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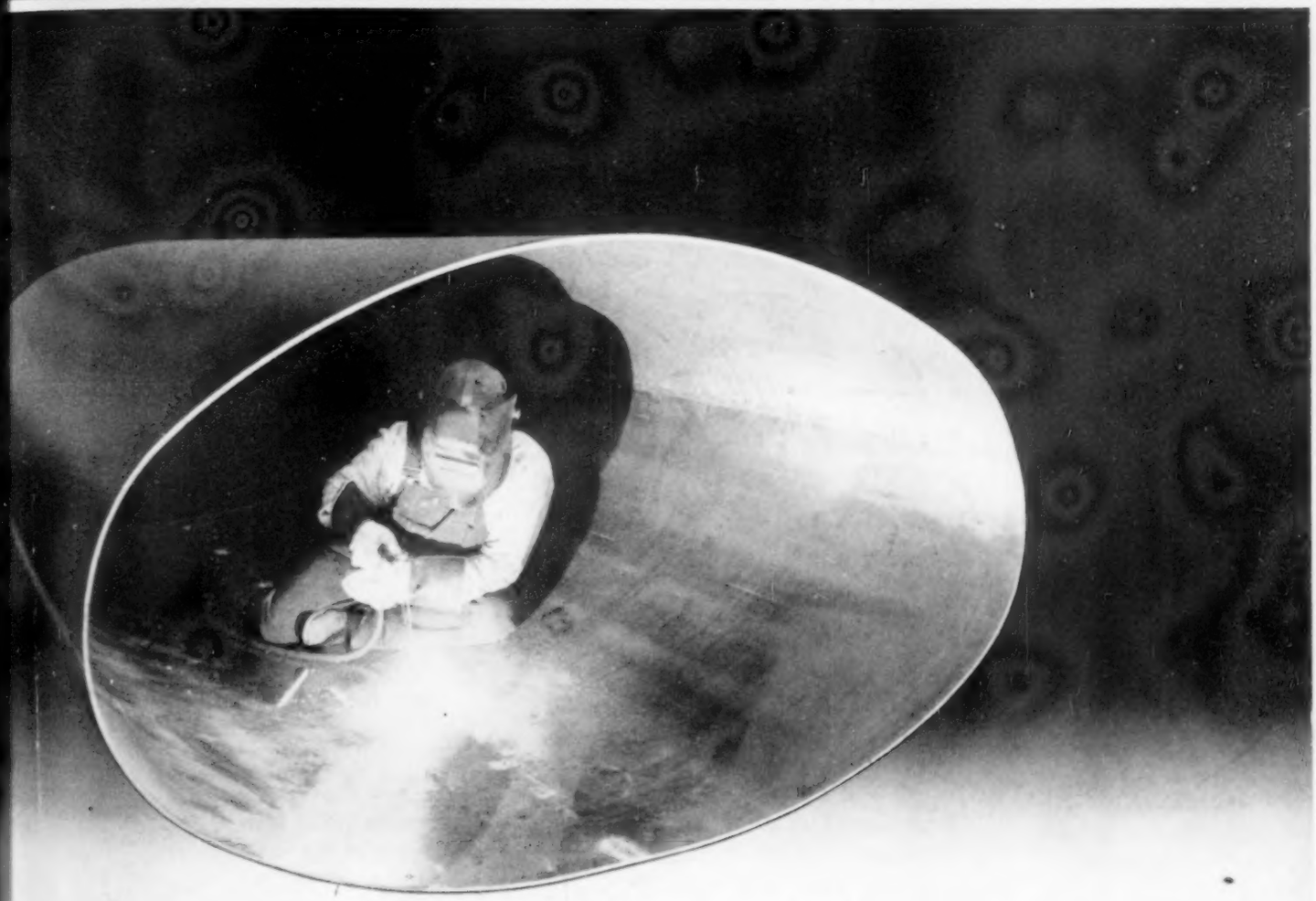
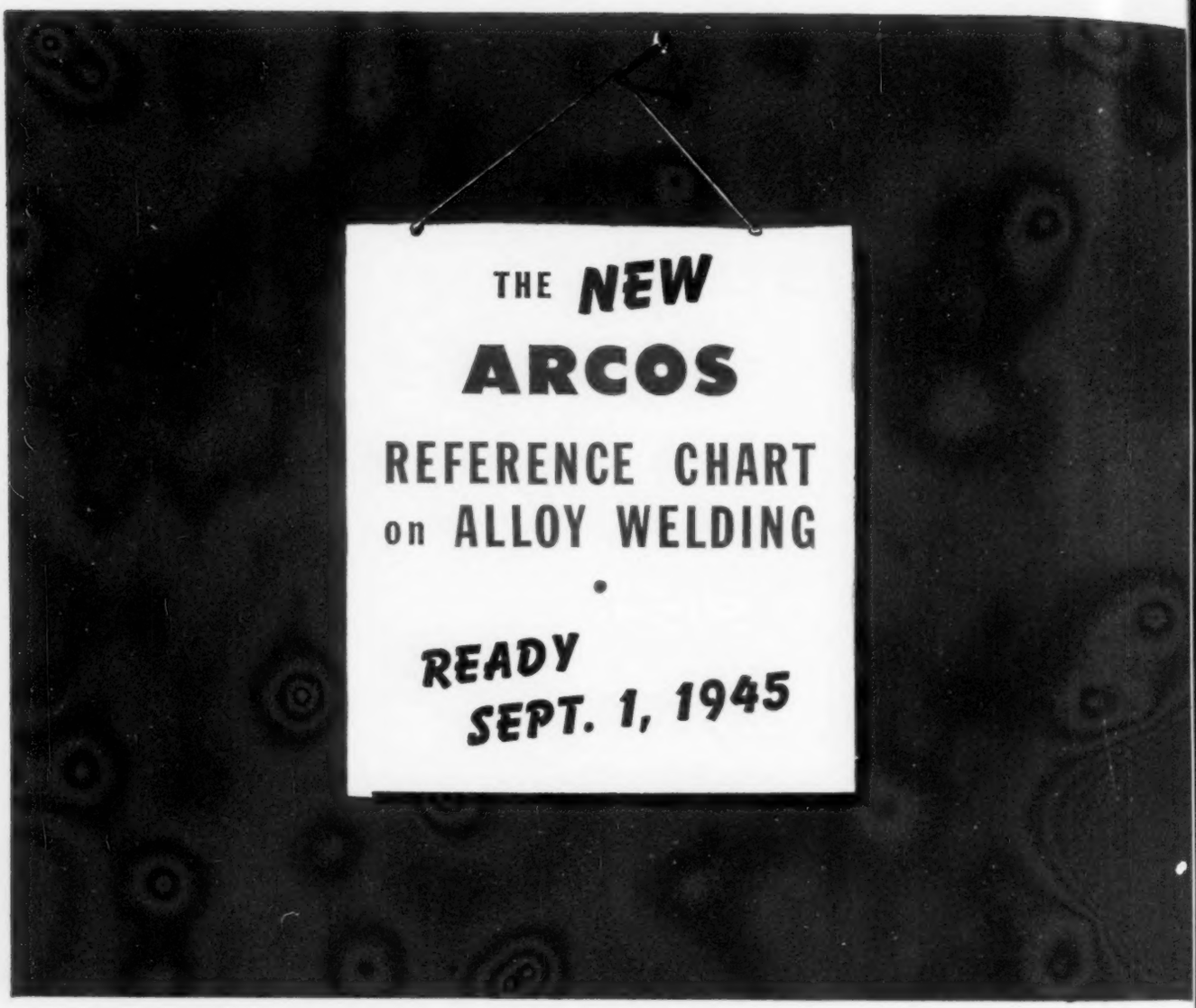


The Journal of the American Welding Society



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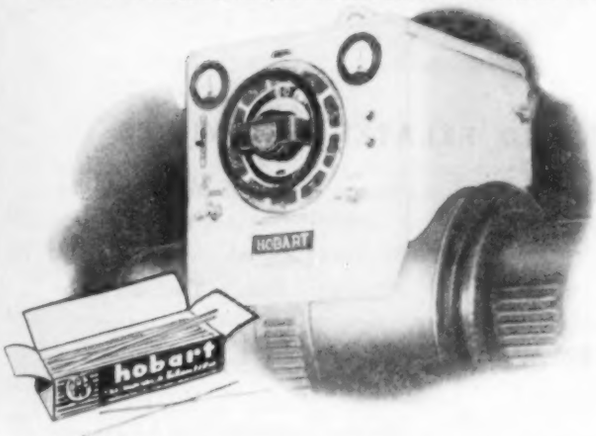

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The Journal of the American Welding Society

Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

AUGUST, 1945

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COVER

Fabricating Stainless Steel Transport Tank. *Courtesy, The Heil Co.*

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The Journal of
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Resistance Welding Fundamentals

By F. R. Woodward*

RESISTANCE welding is the process of joining two or more metallic parts to form an assembly, the heat for the formation of the weld being created by the resistance of the parts and welding machine electrodes to the passage of electric current supplied by the welding machine.

Fundamentals

Arrangement of the resistance welding equipment components is illustrated in Fig. 1. It consists of: a rigid frame housing a high secondary current welding transformer; the electrodes for contacting the work; the conductors connecting these electrodes with the welding transformer; means for exerting electrode pressure on the work; means of current regulation, either by regulation of transformer turns ratio as illustrated, or by electronic control; a contactor to interrupt the power to the welder transformer; and a timer which is capable of controlling the action of the contactor within the limits of accuracy required to produce the desired weld characteristics.

An illustration of a typical resistance welding process, such as spot welding, is shown in Fig. 2 and indicates the composite effects of heat generation and losses for this process. The heat being generated in these parts is expressed by the formula,

$$W = I^2Rt$$

where W is heat in watt-seconds, I is amperes flowing through the weld, R is the resistance in ohms and t is the time in seconds.

* Welding Engineer, Resistance Welding Engineering Dept., Motor Div., Westinghouse Electric Corp., East Pittsburgh, Pa.

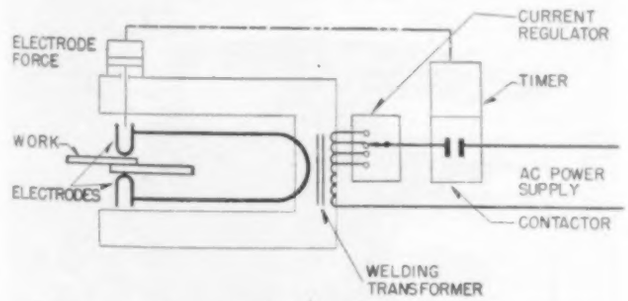

Fig. 1—Resistance Welding Equipment Components

The general arrangement of the components making up a resistance welding machine is illustrated above. These elements include: a rigid "C" shaped frame that (1) houses a high secondary current welding transformer and (2) provides electrode support; conductors to connect the electrodes with welding transformer; electrode pressure source; means of current regulation, either by varying the transformer turns ratio, or by electronic control a contactor to interrrupt the power to the welding transformer; and a timer that can control the action of the contactor within the limits of accuracy required to produce the desired weld characteristics.

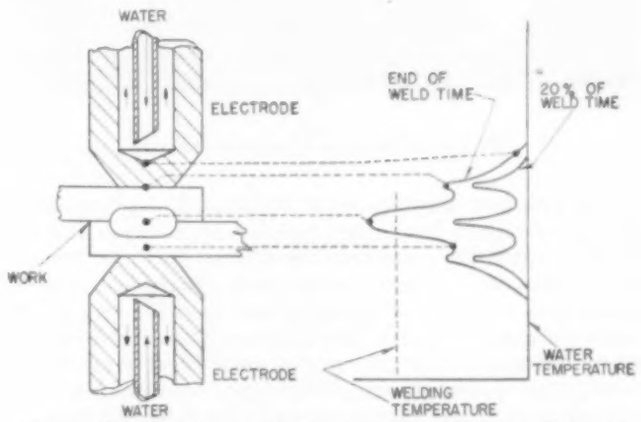

Fig. 2—Temperature Gradient of Spot Welding Process

The composite effects of heat generated and lost is illustrated in the above sketch. The heat being generated in the work being welded and the welding electrodes is expressed by the formula, where;

$$W = I^2Rt$$

"W" is the heat in Watt-Seconds,
"I" is the current Amperes flowing through the weld,
"R" is the Resistance in Ohms, and
"t" is the time in Seconds.

Not all of the heat is generated at the proper point, at the juncture of the weldments (parts being welded). The flow of heat to or from this point, which in turn assists or retards the creation of the proper localized welding heat, is governed by the temperature gradient established by the welding current acting on the various resistive components.

Factors effecting the amount of heat being produced by a given welding current for a unit of time are:

1. The electrical resistance of the materials being welded.
2. The electrical resistance of the electrode materials.
3. The contact resistance between weldments as determined by surface conditions, scale, welding pressure, etc.
4. The contact resistance between the electrodes and weldments as determined by surface conditions, area of electrode contact and welding pressure.

The weld heat losses are due to the conduction of heat by the electrodes and the material in the weldments from the localized area where it is desired to produce the weld.

Not all of the heat is generated at the proper point—at the juncture of the weldments (parts being welded). The flow of heat to or from this point, assisting or retarding the creation of the proper localized welding heat, is governed by the heat gradient established by the welding current acting on the various resistive components.

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The weld heat losses are due to the removal of heat from the weld area by the electrodes, usually water-cooled, and by the material in the weldment themselves from the localized area where it is desired to produce a weld.

In order to produce a strong weld, it is usually necessary to bring the "faying" or contacting surfaces of the weldments up to their respective welding temperatures at the same time and cause a blending of a portion of each weldment in the formation of a "weld zone," "nugget" or "slug," terms usually typical of a certain type of resistance welding. Thus it is difficult to produce a satisfactory weld between dissimilar metals which will not alloy, and any weld so produced—often termed a "stick" weld—will be nothing more than a surface molecular interlocking joint.

Product Design Considerations

The primary advantage of resistance welding in the joining of metals lies in its speed of operation. Because of the desired high speed of operation, and also because heat losses in the weldments and electrodes must be minimized to prevent warping and burning, each weld must be made in a very short time. Thus, the instantaneous welding power required is considerable even for a thin gauge welding job. Therefore, resistance welding is applied most advantageously to thin metal fabrication. The heavier materials require more heat and power and can usually be best fabricated by means of arc or torch welding, etc.

Since the advantage of resistance welding lies in speed, better advantage of the process may be derived by designing the product to be welded so as to permit the use of as simple a welding machine as possible. It is especially important that the product be so designed as to avoid complicated current carrying members in the welder which must be cleared when loading the parts into the machine.

If possible, the product should be designed so that simple electrodes may be used in the welder. This is because the more complicated electrodes usually require quite intricate passages for the proper water cooling so essential for a high rate of production and reasonable maintenance cost of the welder.

Since electrode maintenance is usually a considerable factor on any resistance welding equipment, it is advisable that care be taken that the parts coming to the machine are properly cleaned, having little or no dirt, scale, dust or other materials which may tend to burn or foul the electrodes.

Spot Welding

Spot welding is that resistance welding process which units two or more flat sheets of metal by concentrating both pressure and the welding current at a point by means of relatively small electrodes.

In practice the spot welding process must embody a synchronization of the mechanical operation of the welding machine with the application of electrical energy through the electrodes and material, so that application of pressure will both precede and follow after the application of the welding current. This is to insure that full electrode pressure shall be attained prior to the welding discharge, and that this pressure be maintained afterwards until the weld "nugget" shall have cooled to a temperature where it regains a large portion of the inherent metal strength. The cooler, harder material surrounding this weld nugget is thus forced by the welding pressure to move along with the inner plastic core of the weld as the latter shrinks during the cooling process. Cracks in welds are therefore an indication of the possibility of an excessively short "hold" time after cessation of welding current flow.

The length of application of welding current is dependent entirely on the materials being welded and the inherent characteristics of the welding machine itself. For instance, if the machine should be somewhat deficient in pressure available, it will be impossible to use the higher values of current without expelling weld metal, and a longer weld time period with a lower current value must be used to produce the weld. Furthermore, the dynamic pressure characteristics of different types of machines may be sufficient to change considerably the optimum welding set-up values required for a given welding job. This is one reason why there is considerable diversity in opinion regarding proper welding set-up for any given job.

Multi-Heat Timing Controls

The use of so-called "pulsation" welding; that is, the repeated application of weld power while maintaining electrode pressure on the work; is advantageous because this process permits the building up of spot diameter with relatively long over-all time of power applications. This timing control permits the welding of heavier materials with a given machine than would otherwise be possible since the pressure requirement for the production of a satisfactory weld is about 30% lower than that required for a single impulse weld. The current used for the production of a pulsation weld is also about 30% less, although the total time of application is usually about 200% longer. Pulsation welding is preferable on low conductivity materials (less than 20% of copper, International Annealed Copper Standard) where the materials being welded are greater than one-eighth inch in thickness. Thus, on any machines expected to weld heavy material, the slight additional expenditure for this feature is well justified.

"Program" timing is a variation of pulsation weld-timing which consists in unequal lengths of time of power application with unequal "cool" times interposed between. This process is particularly useful when welding those steels which harden when cooling from the

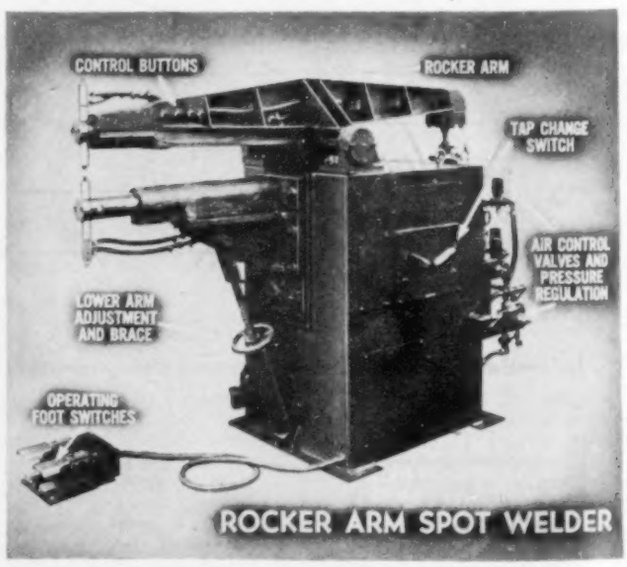

Fig. 3

welding temperature. By the use of this control, the steels may be preheated, welded, tempered, and refined in grain structure, all automatically in the welding machine by proper timing of the current impulses.

Spot Welding Machines

Many types and modifications of spot welding machines are manufactured at present by welding equipment manufacturers. Probably the more common of these types is the rocker arm spot welder, an illustration of which is shown in Fig. 3. This is one of the larger, higher speed machines of this type, mechanically operated by air pressure which is controlled by means of a number of solenoid valves mounted at the rear of the machine, and operating an air cylinder, also at the rear, connected to the back end of the "walking beam" or rocker type upper arm. Thus, the welding pressure is applied at the electrode with a minimum of equipment near the electrodes. This permits easier handling of parts to be welded. The electrodes and electrode holders are water cooled, and the lower arm is adjustable in height. The welding transformer is located inside the frame of the machine, with a tap switch mounted on the side of the frame for convenient adjustment of secondary voltage. The adjustment is obtained by varying the number of primary turns of the transformer.

Other types of rocker arm machines are mechanically operated by hydraulic fluid. Others are cam operated, the cam being driven by a motor working through a gear box. Still other lighter machines are operated by foot pressure where pressure requirements of the machines are not excessive for this method of application.

The "press" type spot welder is quite similar to the rocker arm except that the upper electrode assembly is carried by a slide which moves in ways with a vertical motion. With this type machine, accurate electrode alignment is not disturbed by a variation in the thickness of the work being welded or by a change in the length of the welding electrode in use. Press type spot welders are also supplied with air, hydraulic, cam or foot operation for mechanical movement and pressure requirements.

Another type of spot welder is the "gun" or portable welder, which is shown in Fig. 4. The control equipment and transformer is usually mounted more or less stationary. The gun which carries the electrodes and pressure actuating mechanism is usually counterbalanced to prevent undue operator fatigue and connected to the transformer by means of flexible cables which carry the secondary current from the transformer. Water cooling lines and control cables also go from the stationary

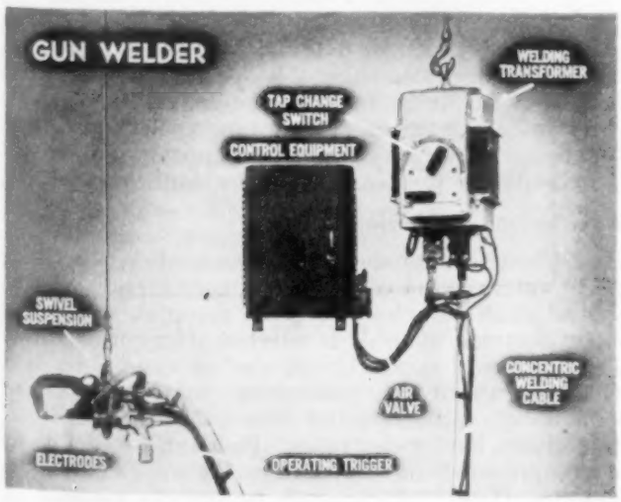

Fig. 4

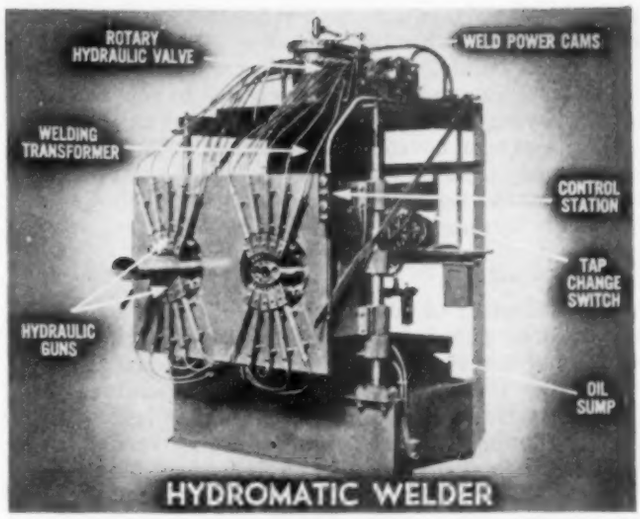

Fig. 5

equipment to the guns so that full control of the gun may be maintained by the operator. Gun welders are particularly useful in welding large assemblies which cannot be moved to a stationary welding machine. These assemblies must frequently be held in position to close limits by means of rigid jigs, necessarily rather cumbersome to handle.

Another type of spot welding equipment is that known as "hydromatic" or "oil spot." A type of this equipment is shown in Fig. 5, which in this case accepts two complete automobile muffler assemblies of four parts as illustrated at the base of the machine. This machine when loaded and initiated by the welding operator transmits hydraulic pressure, from the rotary hydraulic valve at the top of the machine, individually in sequence to each of the ten welding guns on each side. A rotary weld initiating cam is synchronized with this hydraulic valve. Thus, in operation, the first gun contacts the work under pressure, the weld current flows through the electrode for a preset time value, the gun moves to the retracted position, and the second gun starts its cycle. The welding of each baffle in the tube is thus accomplished automatically with a minimum of operator attention. The welding transformer in this case is located inside the framework and its secondary voltage controlled by means of taps on the primary windings brought out to a tap change switch shown on the back of the machine. A machine of this type is always built for a particular welding job and thus requires special design and application efforts.

Electrode Materials

The electrodes of any resistance welding machine are of prime importance, both from a standpoint of production quality, and a reduction in operating cost and maintenance. Electrode materials must have rather high conductivity in order to carry the large currents required without burning or blistering, with its attendant work-marring effects. Electrodes must also have considerable mechanical strength in order to withstand the high welding pressures and repeated impact on the material being welded. Since, in operation, the electrode face becomes quite hot, it is desirable that its material have an annealing temperature as high as possible.

Various electrode manufacturers are marketing materials which combine hardness and good conductivity to a remarkable degree. Different alloys give varying combinations of these qualities. One alloy may have a conductivity of 80% of pure copper and have a hardness

of Rockwell 68B, while another has a hardness of 100B but only 29% conductivity (see Fig. 10).

Therefore, it is necessary to select the proper electrode material having sufficient conductivity to prevent burning or alloying of the tip face, and also be hard enough to retain its proper contour in operation. An engineering compromise is usually necessary between these two features since no electrode material can have both maximum hardness and conductivity.

Electrode Usage

Proper cooling of the electrodes, obtained by passing two to three gallons per minute of water having a temperature of less than 70° F., will be of material aid in reducing the "fouling" by reducing the temperature of the electrode surface to a point where it has less tendency toward alloying with the material being welded. The strength of the electrode material also will be considerably greater if the temperature be maintained at a low value. The surface temperature of any electrode may be reduced by the following means: use of electrode materials having high electrical and thermal conductivity; use of low temperature cooling water impinging at high velocity on the inner surface of the electrode, use of electrodes having their inner surfaces corrugated or finned to increase heat transfer rate, and maintenance of a clean well fitting joint between the electrode and the electrode holder.

The maintenance of a given contour or tip diameter during production is necessary to control the welding results obtained on a given machine. If the control required is not particularly critical, tip maintenance may very well be accomplished by the operator using a file on the electrodes, while they remain in the machine.

If the welding being accomplished is on critical materials or on jobs which require very consistent results, it will be necessary that the electrodes be machined periodically on a machine tool in order that the electrode diameter or contour may be re-established perfectly before they change to a degree which may affect the weld consistency.

Adequate electrode pressures result in the following effects contributing to good welding results:

1. Production of local intimate contact, concentrating current flow to the desired area.
2. Reduction in weld porosity caused by low boiling point of certain elements.
3. Assistance in reducing cooling cracks by compensating for internal shrinkage with an external follow-up pressure.
4. Reduction of the tendency for the electrodes to alloy with the material being welded.

Electrode Design

There are two general types of electrode faces in favor at the present time for spot welding. The "dome" type has a spherical radius formed on its working face. The optimum radius of this dome usually increases with the yield point of the material welded, and also with the thickness of the material but to a lesser degree.

The "flat" type electrode may be flat for the full area of the electrode to reduce weld marking of the material, when its mating electrode must provide additional localization of heat and pressure; or it may be flat for a reduced section at the tip of a truncated cone form, the sides tapering back to the full electrode section at an angle of 30 to 45° to the face. With this type electrode, the minimum diameter of the contacting face is usually $2t + .1$ in., where "t" is the thickness of the contacting sheet of material.

In use, the flat electrode retains its shape better than the dome type but is more difficult to clean or resurface repeatedly in the welding machine and still maintain proper contour. Thus, when welding materials which necessitate frequent cleaning of electrodes, dome tips are preferable.

A commonly accepted electrode for use on mild steel or other non-critical welding materials is one having a flat face with a radius edge, contributing to ease of maintenance but not lending itself to precise control of welding conditions. The use of the formerly popular "conical" tip whose sides of face are 7° or 11° angled from the plane of the surface welded, was a concession to the relatively high conductivity of aluminum, and was useful in lowering the power requirements of the material, but at the expense of quality of weld and final surface appearance. This tip is not satisfactory for aluminum welding for aircraft fabrication.

Welding electrodes should be easily removed from their holders to facilitate replacement for remachining or substitution of a new type required. Types of electrode mountings or means of clamping are too numerous to detail, all having their peculiar advantages—and disadvantages.

The most common mounting, however, is that of a tapered shank electrode inserted in a correspondingly tapered socket in the point holder. The more common taper is known as "Morse taper," in which the included angle of the taper is about 3°. This taper is very satisfactory for sealing the internal water pressure necessary for proper circulation of tip coolant. However, with this slight taper, large expanding forces are created by the welding force necessarily imposed on the electrode face. Thus, with welding forces over 500 pounds on the $^1/_2$-in. diameter electrode and 1000 pounds on the $^5/_8$-in. electrode, expanding force becomes excessive, resulting in distortion of the point holder and extreme difficulty in removing electrodes. The above loadings, however, are no more important than the impact loadings developed when the electrodes contact the material being welded. No convenient means of measuring this impact value is ordinarily available to the user other than noting the rate of deterioration of electrodes and holders.

To enable the use of medium diameter electrodes at higher welding pressures and to facilitate tip replacement (features necessary for aircraft aluminum welding) the so-called 6 degree taper tip was developed. This electrode has an included angle of taper of 12°. It is not very satisfactory for sealing the coolant pressure and is not usable at any great degree of angularity with the work—transverse forces tending to loosen the tip in the holder.

More useful tapers are those developed and used by Fisher Body Division of General Motors, a tip having included angle of about 6°; and by Ford Motor Company, having included angle of 8°. These tips are usable at much higher pressures than the conventional Morse tapers and are satisfactory in sealing coolant pressures. More universal usage of one of these tapers is anticipated after cessation of present wartime standardization efforts.

Determination of Welding Set Up

It is possible to predict the approximate spot welding set-up values required from an examination of the physical characteristics of a given material. Thus, the proper electrode material is selected after consideration of the electrical conductivity, surface conditions, and yield strength of the weldments' materials. Lower conductivity of the material allows the usage of lower conductivity, harder electrodes. Poor surface conditions are compensated for by softer, higher conductivity electrodes. Low yield strengths enable the use of high conductivity electrodes, because these softer electrodes

will not "mushroom" excessively at the lower welding pressure required.

The time of power application or "weld time" required for the production of a spot weld, having best characteristics of internal weld and external appearance, appears to be governed almost entirely by the thickness of the materials being welded unless there are surface conditions which must be overcome during the welding process, such as rust, scale or oxide which prevent the passage of the proper welding current during the initial portion of the cycle.

Too short a weld time necessitates larger welding currents which result in "splashing" of molten metal from under the electrodes contacting faces as well as the production of a thin weld "slug" or "nugget" at the materials' interfaces which has insufficient ductility or strength for most design requirements.

A weld time of too long duration results in excessive heat losses which cause discoloration or burning of material surrounding the weld, unnecessary warping or buckling of the welded assembly, and rapid electrode deterioration.

As a general rule, the weld time may be set up as equal to 150 to 250 cycles per inch thickness of the sheet, where one cycle is $^1/_{60}$ second. Few spot welds require less than three cycles for good results. Timing of less than five cycles should never be used with non-synchronous equipment. If welding equipment is deficient in pressure or welding current, or has high mechanical inertia, it will be necessary to increase weld time to get best results.

The pressure requirements for a spot weld are determined by the material's thickness, yield strength and surface conditions. The stiffness of a sheet is proportional to the cube of its thickness, but since a longer weld time is used on thicker material, the weld current reduces this yield strength effectively until the pressure requirement for a spot weld is almost directly proportional to the thickness of the material. This pressure requirement is also proportional to the yield strength and is increased by presence of scale, dirt, or other coatings on the material.

Thus, while 0.050 in. thicknesses of hot rolled, mild steel, pickled, can be welded readily with 600 pounds tip force, thicknesses of 0.100 in. will require 1200 pounds for best results, and a steel such as NAX 9115 having twice the yield strength of mild steel, will require 1200 pounds for best results on 0.040 in. thicknesses. Presence of coatings such as galvanizing, etc., or scale, increase pressure requirements about 30% for best results.

The current required for a spot weld is, of course, determined somewhat by the preceding factors of electrode contour, weld time, and electrode force or weld pressure. To an even greater degree, this requirement is based on the electrical conductivity, thermal conductivity and melting point of the materials welded. Since the thermal conductivity is, to a degree, proportional to the electrical conductivity, and is largely related to the heat losses of the weld power, it can be safely neglected. The melting point, while not necessarily the actual forging temperature required for welding, is a very important characteristic in estimating the weldability of dissimilar metal combinations.

Positioning Devices

Jigs and fixtures are necessary on many welding jobs in order to align perfectly the parts to be welded so that the completed assembly may perform its function properly. These fixtures must be built so that they will not allow "short circuiting" of the secondary current from the point of welding through which the current should be directed. In order to maintain proper production, fixtures should allow rapid loading and unloading of the parts, and if the fixture is to be used at a stationary machine, it should be light enough to permit rapid handling without operator fatigue. If the fixture is to be used with portable or gun type welders, it may be considerably heavier, but should be designed to provide proper clearance for the gun being used in order to reach conveniently all parts to be spot welded.

Machine Maintenance

In regard to machine maintenance, little can be said except that each machine has its own maintenance requirements, governed largely by its engineering design. With all types of machines, however, the entire secondary circuit should be dismantled and cleaned with steel wool at intervals from one month to three months, depending on industrial atmospheres and weld consistency results desired from the machine. With air operated machines a troublesome item is that of air valves, requiring frequent magnetic solenoid replacements. Cam operated machines usually require considerable maintenance on the gear box and clutch between the driving motor and the operating cam.

Seam Welding

Seam welding is very similar to spot welding except that the stationary electrodes of spot welding are replaced with welding wheels, together with some means of causing rotation as they move along the work being welded. The wheel electrodes usually move the work at a rate of from two to fifty feet per minute. At the higher speeds the current application may be continuous, in which case each half cycle of alternating current produces a small weld overlapping the previously formed weld to form a continuous seam.

Welding Set Up

One-twelfth of an inch is a satisfactory spot spacing on No. 22 gage materials to produce a continuous seam weld. On heavier materials, however, the spot spacing must be greater in order to prevent excessive "build-up" of heat ahead of the welding wheel. It is necessary, when striving for best welding results, to interrupt the welding power so as to provide necessary "off time" for the cooling of each individual weld spot. Spot spacing for seam welding two pieces of $^1/_8$-in. material should be about $^1/_5$ in.

As a rule, we can say that the seam welding of mild steel can be accomplished very well having "heat" and "cool" periods of equal duration. Materials having a higher conductivity require a longer "cool" period, and materials having a lower conductivity may be welded quite satisfactorily with a shorter "cool" period. With 60 cycle power supply, the relationship of weld timing, wheel speed and spots per inch may be indicated by the equation: $t_w + t_c = \frac{300}{VN}$,

where: t_w = weld time in cycles
t_c = cool time in cycles
V = velocity or speed of welding in feet per minute
N = spots produced per inch

Seam Welding Machines

The classification of different types of seam welding machines is rather complex. In the first place, most seam welders are air operated as far as the mechanical pressure requirements are concerned. In regard to the

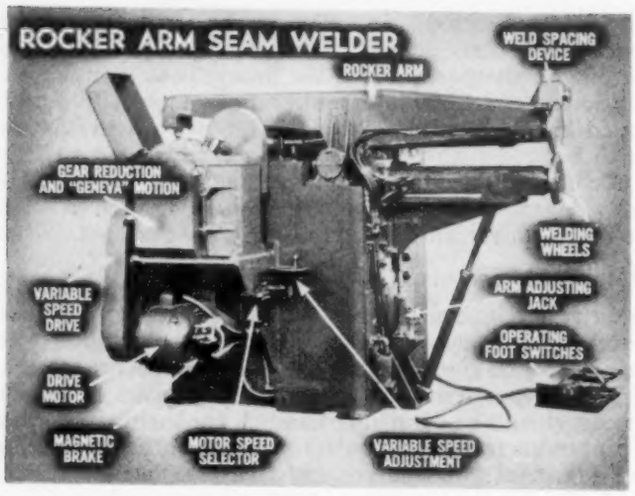

Fig. 6

method of operating the upper electrode, the machines may be classified as rocker arm and press type. The rocker arm machine is illustrated in Fig. 6 which shows a heavy duty type manufactured for the seam welding of aluminum and carrying a special "geneva" drive for intermittent motion of the welding wheels. This machine was built for the production of quality spots in thicker aluminum alloy sheets.

The wheel arrangement of the machine illustrated is "circular," similar to the type of wheel arrangement that would be used for welding the circular bottom in a pail. If the wheels were arranged for carrying the material back over the lower or upper arms such as would be necessary in welding the longitudinal seam of a drum, the wheel arrangement would be called "longitudinal." If changes in wheel arrangements are possible on the same machine, the welder is termed a "universal" machine and may be changed from "circular" to "longitudinal" and vice versa at any time desired.

A machine is also described by its method of driving the welding wheels, such as "gear drive," in which one of the welding wheels is driven by a gear on the spindle, carrying the welding wheel. In this case the peripheral speed of the welding wheel will change as the diameter of the wheel changes with wear. The machine may be "knurl driven," in which case one or both of the welding wheels are engaged by friction with a knurled wheel, which is in turn gear driven by the drive motor. In this case the welding wheels may be of different diameter and still drive with equal peripheral speed if the knurls themselves are of the same diameter and have the same speed. Some special machines are work driven, the welding wheels actually being driven by friction in contact with the work as it is pushed through the machine by an external power source.

Seam Welding Electrodes

Practically the same considerations, in regard to the electrode materials, apply to the seam welding as were mentioned under spot welding. In addition, it is desirable to design the seam welder in order to automatically trim the welding wheel to the desired width. This can be accomplished by proper design of the driving knurl, or by using an idler knurl as a trimming device on gear or work driven machines.

The cooling of seam welder wheels is highly important in maintaining wheel life and usually necessitates an external spray of water on the welding wheels and work, since most seam welder wheels are not cooled internally. A large volume of water is often necessary in order to prevent wheel deterioration and to obtain satisfactory welding results. Welding entirely submerged is extremely advisable on small parts which justify the manufacture of a special machine.

Intermittent Seam

Most seam welding machines weld through two pieces of material, which are "lapped" together, so that there is a double thickness of material at the joint. If the welded joint is not continuous, or the individual weld spots do not overlap, then the weld is termed a "roll spot" or a "stitch weld."

Butt Seam

Some welding machines of a more special nature are used to produce a butt seam joint such as used commonly in the fabrication of the longitudinal seams in pipe or tubing. In this type of machine, as illustrated in Fig. 7, the material is formed to a cylindrical shape by equipment not illustrated and fed into the machine from the right, with the seam or slit in the tubing upward and guided by the seam guide wheel which penetrates in the slit in the unwelded tubing. The tube then progresses on between the upper and lower entering rolls to the welding wheels (the larger wheels illustrated) and the side pressure rolls, where the actual tube welding is accomplished.

The welding wheels are connected by two flexible bands to the transformer overhead, whose secondary voltage is regulated by means of the illustrated primary tap change switch. This tubing is usually welded at high speeds using continuous power application with no interruptions other than the inherent 60-cycle alternations. Hand wheels provide full adjustment for varying the position of the welding and positioning rolls in order to accommodate various size tubing.

Machine Maintenance

One of the most troublesome maintenance items on seam welders is the spindle carrying the welding wheel and the bushing in which it turns. These bushings or bearings render a very difficult service; since welding pressures are often quite high, temperatures reached often are 300 to 400° F., and the welding current of many thousand amperes flows from spindle to bushing through a film of lubricant which is only slightly conducting at best. Graphite bearing lubricants have proved very successful in most seam welder applications as a main spindle lubricant.

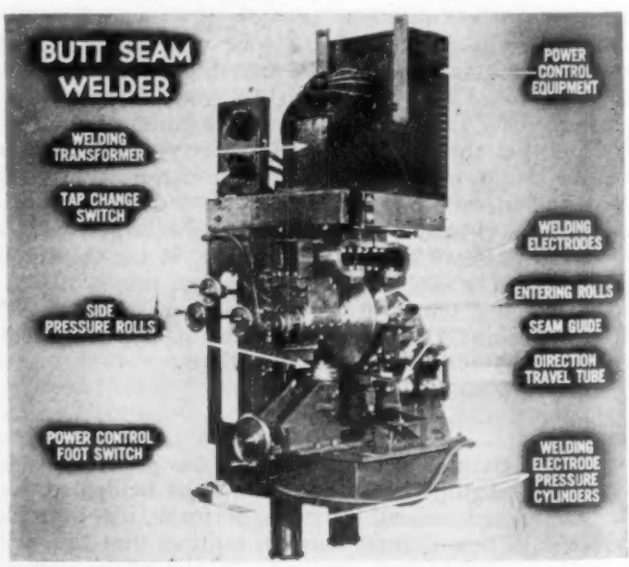

Fig. 7

Projection Welding

Projection welding is that method of resistance welding in which the localization of pressure and current is accomplished by means of irregularities formed in one or both of the weldments being assembled. These irregularities allow the use of flat, plain or die type electrodes on the welding machine itself. Current densities on the dies are likewise decreased, allowing the use of lower conductivity, harder electrode materials, which results in considerable reduction in electrode or die maintenance on this type of equipment.

The method of projection welding allows the close placing of several welds because of the fact that all welds are made simultaneously so that there is no "shunting" effect from previously formed welds which would tend to absorb a portion of the secondary current produced by the machine for the formation of a weld.

In projection welding it is especially important that the parts to be welded be designed with the thought in mind of creating the proper fusion temperature at precisely the same instant in both elements being welded. For this reason it is desirable that the projections be made in the heavier material so that these higher resistance points will not be burned off before the other flat weldments can be brought up to proper fusion temperature.

Projection welding of aluminum and copper bearing alloys is considered very difficult and requires unusually critical control of the welding machine as well as careful design of the weldment to prevent expulsion of the weld metal on the projections.

Types of Machines

Projection welders are almost invariably of the press type machine in order that the die mounting platens may remain perfectly parallel at all times. The method of obtaining mechanical movement or electrode pressures may be by air, hydraulic or motor operation, or through a cam or toggle mechanism.

A specially constructed machine of this latter type is illustrated in Fig. 8. This machine has a heavy, rigid frame enclosing the welding transformer beside the primary tap change switch shown on the side of the machine. The driving motor is located on top of the frame, and by means of a rubber belt drives a gear box located over the welding transformer inside the frame. The gear box in turn works on a toggle mechanism enclosed in the moving slide of the machine, lowering the upper electrode on the work being welded. The mechanical resistance of the work forces the toggle mechanism, and its attached piston on the top of the frame, to move upward slightly against a regulated air pressure, which provides means for adjusting the welding pressure obtained in operation.

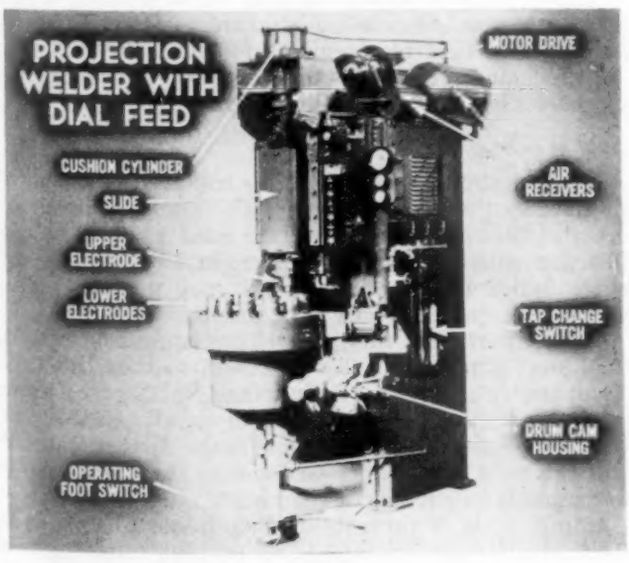

Fig. 8

One of the interesting features of this machine is the rotating table carrying 12 lower dies. This table has an intermittent motion derived from its associated drum cam shown at the lower right front of the machine. One or more operators can thus be loading the table while the machine is running continuously. Production of this machine is approximately 80 welded assemblies per minute of metal radio tubes.

The projection welder machines, as a class, are constructed considerably more rigidly than either the spot welders or seam welders. This is because of the necessity of greater total pressure to make several spots simultaneously and the necessity for maintaining perfectly parallel alignment of die mounting platens, in order that the customary multiple projections may all contact with approximately equal pressure. These welders are usually operated at somewhat lower speeds than are spot welders, because of the extra time requirement for loading and unloading, since only one machine operation is usually necessary to complete the assembly.

As previously mentioned, the customary design of projection welding equipment allows the use of broad, flat, low conductivity, hard electrode materials. The use of these higher resistance materials, with accompanying low thermal conductivity, necessitates very adequate water cooling brought close to the surface of the electrodes in order that the electrode materials shall not become so hot as to result in cracking the hard electrode materials.

In general, it can be said that the process of projection welding offers the most rapid assembly technique of any of the resistance welding methods.

Butt Welding

Butt welding is that resistance welding process which entails placing the butt end of two sections, such as rods or strips, together in firm contact and then passing a heavy current through these members. The current heats the sections, because of their electrical resistance, particularly high where abutting. After the heating has progressed for some time, the material becomes plastic at the juncture and the pressure which has been applied to the members, compresses or "upsets" the weld so that a solidly fused joint results. Because the electrode surfaces clamping the weldments are parallel to the direction of upset force, it is usually necessary that the clamping pressures exerted by these dies be considerably greater than would otherwise be necessary for current conduction. These clamping pressures, great enough to prevent slippage of the section through the dies, are exerted by either hand force working through cams, or by air or hydraulic means. Because the sections being welded are often long, it is customary to build butt welders with the slide or moving platen traveling along a horizontal line.

This process lends itself admirably to automatic wire welding and other work where the power requirements are quite low. On many other jobs, however, an engineering choice must be made between this method and that of—

Flash Welding

The equipment for flash welding is practically identical

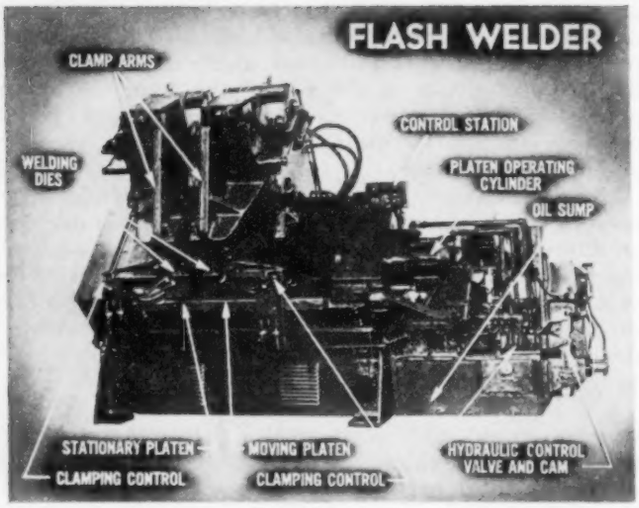

Fig 9

to that used in butt welding. The process differs in that for flash welding the parts are loaded in the machine slightly separated or in very light contact with each other. After clamping by the electrodes, the power is turned on, applying a voltage between the weldments. Movement of the traveling platen is initiated at the same time and accomplished by hand operation, air or hydraulic pressures, dependent upon pressure requirements of the machine. When incidental contact is established between the weldments, the voltage across these parts is sufficient to cause a sparking or flashing, which throws off molten particles of metal in a vigorous manner. This flashing continues as the moving platen goes forward until the entire area to be welded is flashing vigorously, and the heat from this flashing has progressed back into the weldments to a degree that they are sufficiently plastic to be forced together quickly or "upset," which squeezes out any burned metal, slag, oxide, or other impurity which would otherwise weaken the weld joint. Immediately following this upset movement, the welding power is interrupted, allowing the weld to cool.

In practice it is necessary to create a constantly accelerating rate of travel of the moving platen in order to maintain the proper rate of flashing at the weld. This is due to the greater effectiveness of the weld current in "melting off" or "blowing out" material at the weld line as the material is heated during the flashing process.

On heavy sections of material, it is customary to point or deform one of the butting surfaces to reduce the initial area of contact. This enables the use of a lower secondary voltage for starting the flash when the materials are cold. Use of an unnecessarily high secondary voltage results in easy starting of the flash, but the voltage has an explosive effect at the latter portion of the flashing period which "blows out" larger particles of metal from the weld zone. This results in an irregular surface at the time of upset which often produces a finished weld which contains slag inclusions, cast material, and porosity, all of which detract from the quality of the flash weld.

Because of this flashing and upset process, the metal at the joint is thickened considerably and it is usually necessary to finish this surface by shearing off the flash while still hot, or by machining when cool.

Flash welders are usually classified according to method of clamping and to the drive mechanism. Methods of clamping are: hand operated, air, or hydraulic. Methods of driving are: hand operated, working through either a single or double toggle mechanism in order to obtain the desired pressure; or by motor driven cam, generated to give the proper rate of acceleration of the moving platen during the welding process; or by hydraulic means, usually controlled by means of Servo valves in turn governed by cams cut to give proper flashing acceleration.

A machine of this latter type is illustrated in Fig. 9, showing the welder bed tilted at a 30° angle in order to facilitate loading and unloading. The stationary platen, together with its clamping mechanism, is on the left; the moving platen, etc. on the right; the driving motor, hydraulic pump, hydraulic control mechanism, and cylinder are all mounted on the right of the machine, exposed for convenient maintenance. The welding transformer of the machine is located inside the frame and fully protected against hot flash created during the welding process.

Maintenance requirements on this type of machine are aggravated by the fact that flash welders are inherently dirty machines, creating their own dirt or flashing dust which penetrates all lubricated surfaces unless fully sealed or made dustproof.

Electrical power control equipment for butt and flash welding is relatively simple, since it is only necessary to be able to interrupt this power at a predetermined point near the operation of the upset movement. Thus, a limit switch is usually satisfactory for timing this operation.

Materials which can be welded by other resistance welding processes can be fabricated with flash welding. This method apparently gives less difficulty in producing a proper union between dissimilar metals because of the intense localized heat of the arc or flash.

Materials to Be Welded

Low-Carbon Steel

Low-carbon steel is the most commonly welded material, and its weldability has become a basis of comparison for that of all other metals and alloys. It is easily welded because fusion may be accomplished in a broad plastic range of temperature, so that precision control of the welding conditions is not always necessary. In the hot rolled form the steel is supplied in a great variety of surface conditions. When clean and free from mill scale, welding electrode life is very good.

Figure 8 shows the standards of the Resistance Welder Manufacturers' Association in regard to minimum physical and electrical requirements for electrode materials. Also included are the names of some of the commercial electrodes in the various classes of materials.

Spot Welding

Table 1 shows welding set up conditions which will produce spot welds in this material. These values shown are the basic values and will be used as such in conjunction with multiplying factors, in order to conveniently indicate the recommended spot welding set up values for other materials to be discussed.

A large portion of the spot welding equipment used on mild steel is not controlled precisely, so that this table is not usable on material thinner than No. 22 gage if power control is by non-synchronous equipment. In this case, weld time should be five cycles for the thinner materials and the weld current decreased from the values shown to maintain an equivalent weld heat.

If mill scale is present, it is desirable to use softer electrodes, longer time and lower current value together with higher pressure. Electrode maintenance is much

Table 2—Metals and Alloys Basic Factors Applied to Spot Welding (From Comparison of 0.040 In. Thicknesses)

Metal	Condition	Yield Strength .2% Offset	Melting Point °F	Electrical Conductivity % Copper	Electrodes		% Basic Mild Steel Value			
					Class Material ‡	Shape	Electrode Force.	Weld Current	Weld Time	Shear Strength
WROUGHT IRON	HR	30,000	2720	12	1	FR	100	90	100	90
STEELS—PLAIN										
Low Carbon (SAE #1010)	HR	40,000	2760	15	2	FR	100	100	100	100
	CR	50,000	2760	15	2	FR	120	110	100	120
Low alloy	HR	60,000	2750	15	1	FR	120	100	120	120
Alloy	HT	120,000	2720	15	2	FR	200	100	100	200*
Stainless — SAE #321, 347	OH	40,000	2570	2.4	3	FR	120	60	80	140
	FH	100,000	2570	2.4	3	FR	200	70	100	200
STEELS—COATED										
Aluminized	...	40,000	2760	15	1	FR	120	110	100	100
Cadmium-plated	...	40,000	2760	15	1	FR	120	110	100	100
Chrome-plated	...	40,000	2760	15	2	F	110	100	100	100
Copper-plated	...	40,000	2760	15	1	FR	110	110	100	100
Galvanized	...	40,000	2760	15	1	FR	120	110	100	100
Nickel-plated	...	40,000	2760	15	1	F	110	100	100	100
Terneplate	...	40,000	2760	15	1	FR	120	110	100	100
Tin-plated	...				1	F	110	100	100	100
ALUMINUM ALLOYS										
2S	0	5,000	1210	59	1	1"R	80	250	80	22
3S	½H	18,000	1200	41	1	2"R	100	280	80	32
52S	½H	29,000	1170	40	1	3"R	130	300	80	42
Alclad 24S	T	43,000	1070	30	1	3"R	200	320	80	40
MAGNESIUM ALLOYS										
Dow Metal "M" 1.5 Mn	...	27,000	1290	29	1	3"R	130	290	80	28
"J" 6. Al	...	34,000	1140	13.5	1	6"R	170	230	80	33
NICKEL	A	20,000	2625	18.2	2	F	100	120	80	90
	CR	95,000	2625	18.2	2	F	140	140	100	110
NICKEL ALLOYS										
Nichrome 20 Cr	CR	60,000	2550	1.6	2	F	120	50	120	120
Inconel 13 Cr	A	35,000	2570	1.8	2	F	100	40	100	130
	CR	110,000	2570	1.8	2	F	140	60	120	160
Monel 30 Cu	A	35,000	2400	3.6	2	F	100	60	100	110
	CR	100,000	2400	3.6	2	F	140	70	120	140
Nickel Silver 10 Ni	CR	75,000	1850	8.3	2	FR	120	100	120	130
COPPER	CR	48,000	1980	100 †	Mo	3"R	100	350	100	100
COPPER ALLOYS										
Red Brass 85 Cu	CR	70,000	1875	37	13	4"R	120	190	120	120
Yellow Brass 65 Cu	CR	75,000	1710	26	2	4"R	120	150	120	130
Admiralty Bronze 70 Cu	CR	90,000	1715	25	2	4"R	120	150	120	140
Naval Brass 60 Cu	CR	65,000	1625	25	2	4"R	120	150	120	120
Muntz Metal 60 Cu	CR	80,000	1660	29	2	4"R	120	150	120	130
Manganese Bronze 58 Cu	CR	60,000	1645	25	2	4"R	110	140	120	120
Phosphor Bronze 5 Sn	CR	75,000	1920	18	2	4"R	120	120	120	130
Aluminum Bronze 8 Al	FH	105,000	1905	15	2	4"R	120	110	120	150
Silicon Bronze 3 Si	CR	70,000	1865	6.7	2	4"R	120	80	120	130
Nickel Silver 10 Ni	CR	75,000	1850	8.3	2	FR	120	100	120	130
PRECIOUS METALS										
Silver	CR	40,000	1760	106 †	Mo	F	100	350	100	100
Gold	CR	30,000	1945	71 †	Mo	F	100	330	100	80
Platinum	CR	27,000	3225	15	1	F	100	110	100	80
Paladium	CR	32,000	2830	15	1	F	100	100	100	90

† Weldability improved by plating. Difficult in thicknesses over .030".

‡ Resistance Welder Manufacturers Association "Equipment Standards".

* Many alloy steels require heat-treatment after welding for satisfactory physical properties.
See legend below Table 1.

ELECTRODE MATERIALS STANDARDS

EQUIPMENT STANDARDS OF THE RESISTANCE WELDER MANUFACTURERS ASSOC.

	ELECTROLOY	MALLORY	S-M-S	WELDING SALES	AVAILABILITY
GROUP A- COPPER BASE ALLOYS					
Class 1.	Grade A	Elkaloy A	Alloy 101	Tuffaloy 88	Rods, Bars, Forgings
Class 2.	XX - TX	Mall. 3 & Trod. 7	Alloy 103	Tuffaloy 77	Rods, Bars, Castings, Forgings
Class 3.	TB	Mall. 100 & Trod. 1	Alloy W5	Tuffaloy 55	Rods, Bars, Castings, Forgings
GROUP B- COPPER-TUNGSTEN ALLOYS					
Class 10	Electroloy 1W3	Elkonite 1W3	Alloy 1	Tuffaloy 1W3	Rods, Bars, Inserts
Class 11	Electroloy 10W3	Elkonite 10W3	Alloy 10	Tuffaloy 10W3	Rods, Bars, Inserts
Class 12	Electroloy 20W3	Elkonite 20W3	Alloy 20	Tuffaloy 20W3	Rods, Bars, Inserts
Class 13	Electroloy 100W	Elkonite 100W	Alloy 100W	Tuffaloy 100W	Rods, Bars, Inserts

STANDARDS

Minimum Requirements

	PROPORTIONAL* LIMIT		HARDNESS Rockwell "B"		CONDUCTIVITY % of Copper		ULTIMATE TENSILE STRENGTH P.S.I.		ELONGATION % in 2"	
	Cast	Wrought	Cast**	Wrought	Cast**	Wrought	Cast**	Wrought	Cast**	Wrought
GROUP A										
Class 1		20,000		68***		80		60,000		20
Class 2	20,000	35,000	55	75	70	75	45,000	65,000	15	15
Class 3	45,000	50,000	95	95****	45	45	85,000	100,000	10	10
							UMTIMATE COMPRESSIVE STRENGTH P.S.I.			
GROUP B										
Class 10				78		40		135,000		
Class 11				98		30		160,000		
Class 12				100		29		185,000		
Class 13				38 Rockwell C		28		225,000		

* At Room Temperature and sensitivity 1 in 100,000

** Based on Cast Tensile Bars

*** For Section not exceeding 1 inch square

**** 90 Rockwell B on finished rods

Approved
March 15, 1940

Fig. 10

higher and consistent welding results are unobtainable, so that cleaning or pickling of the material is advisable, if economically practical.

Cold rolled steel has a higher yield strength and requires higher electrode pressures for spot welding as indicated in Table 2. This table shows the physical characteristics of the more common structural materials and indicates their effect on the optimum spot welding set-up values. It is assumed that flat electrodes will be of the same face diameter as that shown in Table 1 for the particular gage welded.

Seam Welding

Seam welding of low-carbon steels is accomplished on No. 14 gage with the same weld set-up values as shown for spot welding in Table 1 when welding at a rate of about three feet per minute with equal "on" and "off" times. With normal wheel speeds, values of weld current and pressure necessary for seam welding do not change as much as those for spot welding with a given change in gage thickness, apparently because of preheating effect when seam welding a line weld.

Projection, Butt, Flash Welding

This steel may be easily projection or butt welded. Extreme variations in parts welded and machine characteristics prevent the presentation of any rules for estimating welding set-up values other than suggesting a comparison with the required spot-weld values.

In flash welding solid sections, the upset pressure should be near 12,000 psi. Pressure should be 30% less on thin sections. Flashing time will be about $\frac{1}{2}$ second for each 0.01 in. of material thickness. Thin, wide sections require longer flash time in which to trim edges. Secondary voltage should be only high enough to prevent "freezing" of the material during flash period.

Wrought Iron

This material has a low yield point also, and welds similarly to low carbon steel except that in spot welding, the layers of included slag lower its conductivity, and consequently the required welding current is less. Class 1, high conductivity electrodes are preferable for this material.

Low-Alloy Steels

The use of small amounts of alloying materials in steel making results in a considerable increase in the yield strength. Another result is a decrease in the breadth of the plastic range so that the material appears more fluid while welding. These materials are often welded without removal of scale.

Spot and seam welding of low-alloy steels is only slightly more critical in technique than that of low carbon. From a weldability standpoint, it is much preferable that strength in the finished assembly be obtained by use of low-alloy steels rather than the use of medium carbon steels having the same strength.

Projection, butt and flash welding is accomplished

Table 1—Basic Spot Welding Values Used on Low-Carbon, Hot-Rolled, Clean Steel

Sheet Against Smaller Tip		Smaller Tip		Electrode Force Pounds	Weld Current in Amperes		Weld Time Cycles (1/60 Second)	Spot Shear Strength Pounds
US Gage	Thickness Inches	Flat Diameter	or Spherical Radius		Flat Tips	or Radius Tips		
44	.004	.108"	1"	130	4,100	4,700	3	40
38	.006	.112"	1"	150	4,200	4,800	3	70
34	.008	.116"	1"	170	4,300	4,900	3	110
32	.010	.120"	1"	190	4,400	5,000	3	155
30	.012	.124"	1"	210	4,500	5,100	3	200
28	.015	.130"	1"	240	4,600	5,300	3	260
26	.018	.136"	2"	270	5,000	5,500	4	330
24	.024	.148"	2"	330	5,400	6,100	4	500
22	.031	.162"	2"	400	6,000	6,800	5	750
20	.037	.174"	2"	460	6,600	7,600	5	1,100
18	.049	.198"	4"	600	8,000	9,400	6	1,800
16	.061	.222"	4"	700	9,300	11,400	7	2,600
14	.077	.254"	4"	870	11,300	13,600	8	3,500
13	.092	.284"	4"	1,030	13,000	15,400	10	4,300
11	.122	.344"	8"	1,400	15,600	18,500	14	6,200
9	.153	.406"	8"	1,800	17,900	21,200	20	8,200
7	.184	.468"	8"	2,250	19,200	23,100	30	10,000

For materials other than low carbon, hot rolled, clean steel, the approximate spot weld set-up values of pressure, current, time, and spot strength may be obtained by multiplying the basic values indicated in Table 1 by the percentages appearing in Table 2.

EXAMPLE: .077" aluminum alloy 52S-½H.

From Table 1 a basic pressure value for .077" material is 870 pounds

From Table 2, for 52S-½H, a pressure factor of 130% is indicated.

Thus, proper spot weld pressure is 1.3 x 870 = 1131 lbs.

Also, from Table 2 a radius tip is recommended.

Table 1 indicates a basic current value of 13,600 amperes for radius tips on .077" material.

Table 2, for 52S-½H, shows a current factor of 300%.

Thus, proper spot weld current is 3 x 13,600 = 40,800 amperes.

LEGEND — TABLE 2

A	Annealed	FH	Full hard	OH	Soft
Al	Aluminum	FR	Flat or radius face	R	Radius
CR	Cold rolled	HR	Hot rolled	Si	Silicon
Cr	Chromium	HT	Heat-treated	Sn	Tin
Cu	Copper	Mn	Manganese	T	Heat-treated
F	Flat face	Mo	Molybdenum	½H	Half hard
		Ni	Nickel		

easily with the same technique used on low-carbon steels except an increased weld or upset pressure up to 20%.

Alloy Steels

The use of carbon and other alloying elements may result in great increases in the physical properties of steel. The welding of these heat treatable steels with normal procedures will result in an extremely hard and brittle weld zone which has low impact strength. Therefore, in order to effectively utilize the materials strength, it is necessary to heat treat the welded assembly.

When spot, projection, butt, or flash welding medium carbon steels (0.50 C and less) beneficial tempering may be accomplished in the welding machine by allowing a cool time following the weld and then passing another lower power pulse through the weld. The cool time required is governed by the rate of heat transfer from weld to electrode and by the carbon content of the material.

Seam welding of high-carbon steels is impractical where design strength requirements are high unless furnace heat treatment is employed subsequent to welding.

The flash welding of alloy steels is quite critical in set up requirements. Upset pressures range upwards to 25,000 psi. of cross section. Excessively low pressure results in formation of a porous, large grained weld zone. Pressure higher than necessary results in pushing out from the joint that metal which has been heated to the welding temperature, so that relatively cold parts contact. This produces a low strength weld with "bright spots" or "flat spots" visible at the ruptured weld where no true fusion has taken place.

Stainless Steels

Many types of these steels are produced. They are high in chromium and nickel content and, while usually used in the cold worked condition, often contain carbon for additional strength (to 200,000 psi. ultimate and over). This carbon, when heated to a welding temperature, will gradually precipitate out to the grain boundaries, and in future service, intergranular corrosion greatly reduces the materials' strength. Therefore, resistance welding should be accomplished as rapidly as possible to prevent this precipitation when working with stainless steels containing carbon, unless this carbon is stabilized in the material by the addition of columbium or titanium.

Other than this difficulty with carbide precipitation, stainless steels are easily welded. Conductivity is low so that current requirements are small. Yield strengths range upwards to over three times that of low-carbon steels. With this high yield (120,000 psi.) weld pressures for spot, seam, projection and flash, should be twice the values used for low-carbon steel. Butt welding is not recommended.

The harder, low conductivity electrodes are preferable with stainless steel. Class 3 materials are satisfactory for spot welding and flash welding electrodes. Class 12 materials are excellent for projection welding. Water cooling is very necessary when welding stainless steels.

Coated Steels

As indicated in Table 2, many metallic coatings are supplied on low carbon steels for corrosion resistance or ornamental properties. These materials are quite weldable, the chief difficulty being the low melting point of the coatings which accelerates the alloying of the coating with the welding electrode, with a consequent reduction in its conductivity. To reduce this tendency to a minimum, the following precautions should be observed:

1. Use high conductivity electrodes (Class 1).
2. Use high weld pressures.
3. Maintain low electrode temperatures (Good Water Cooling).
4. Use short weld time.

Since frequent cleaning of the electrodes is necessary domed (spherical radius) contour is preferable for both spot and seam welding.

Coatings seldom cause any difficulty in projection or flash welding because of the greater distance from electrodes to weld zone. Light phosphate coatings can be projection welded, but the high electrode maintenance and inconsistent weld results seldom justify their use.

Aluminum Alloys

Aluminum alloys are numerous and have a wide range of physical characteristics. Conductivity of all alloys is high, necessitating large weld currents. The plastic range is narrow, requiring precise control of welding set up variables. The presence of an insulating film of aluminum oxide on the surface of the materials makes welding results very erratic unless this oxide is removed by mechanical or chemical means prior to welding.

Spot welding times are short in order to reduce alloying or "fouling" of the electrode. Spot weld electrodes are usually of Class 1 material and domed contour for easy maintenance since frequent cleaning is necessary.

"Stored energy" control equipments, capable of delivering large amounts of power for short periods of time, are admirably suited to this material in the light and medium thicknesses. Pressure requirements are often excessive when attempting heavier gages ($^1/_8$ in. and over) because of the short effective weld time.

Seam welding of aluminum alloys requires a "weld time" about three times as long as the "cool time." The "weld" times are usually one-third to one-half of those specified for spot welding. Pressure is about 20% higher and weld current 60% higher.

Butt and projection welding is limited to rather simple straight forward jobs and results are distinctly inferior to the flash welding process for this material. Because of its high conductivity, this material requires a rapid flashing action and upset, the complete operation taking place in $^1/_2$ second on the lightest jobs and in 10 seconds for a solid section one inch square. Upset pressures required range to 20,000 psi. for the higher strength alloys.

Magnesium Alloys

These alloys are very light, of medium strength, and have a very narrow plastic range. They have considerable range in electrical conductivity and required welding current.

In spot welding, the material exhibits a great affinity for welding electrodes, and it is necessary to use high conductivity (Class 1) electrodes with good water cooling and short weld time. These alloys can be spot welded with the "stored energy" control systems manufactured for aluminum welding.

Most magnesium alloy sheets are supplied with a chrome-pickle coating to inhibit corrosion. This coating must be completely removed prior to spot welding by some means such as a motor driven wire brush or by chemical treatment.

Projection and butt welding of these alloys is not recommended. Seam welding is difficult since it requires very precise control of energy, good electrode cooling, rapid work cooling, constant electrode cleaning, and uniformly clean material surface conditions.

Flash welding of magnesium requires a very rapid acceleration during the flashing period, the total flashing time being somewhat less than that for aluminum, and the upset pressure also less in proportion to its yield strength.

Nickel and Nickel Alloys

Nickel is supplied in the annealed condition or in various hardnesses of cold-rolled sheet. It can be spot welded by preferably using flat tips, somewhat more current than that required for low-carbon steel, and, in the cold rolled conditions, higher weld pressure. Some sticking of electrode to material is encountered until the surface of the electrode has been coated with a nickel-copper alloy. Excellent results have been obtained with a flat spot welding electrode with sides having an angle of approach of 10° to the face.

Nickel alloys such as Inconel and Monel have much lower electrical conductivity and somewhat higher mechanical strengths than the pure Nickel. In spot and seam welding, therefore, they require considerably lower weld currents as indicated in Table 2.

The flash welding of nickel and nickel alloys is accomplished at a speed similar to that for low-carbon steel and is quite critical in regard to the relationship of upset movement and current cut off point. This cut off, if too early, results in oxide and cast metal being trapped in the weld. If the cut off of current is delayed beyond 3 cycles past the upset, the weldments may be heated to a point where melting takes place at the grain boundaries, weakening the material. Power cut off point should be at some point within the second or third cycles after upset.

Copper and Copper Alloys

The low resistance or high conductivity of copper presents a serious problem in the spot, seam, projection or butt welding of copper. Spot or seam welding may be accomplished in the lighter gages (to 0.040 in. thickness) by using electrodes of relatively high resistance, such as Group B copper-tungsten alloys or molybdenum alloys. In this case, the heat required for the formation of the weld is largely supplied by the electrodes—not by the resistance of the material being welded.

Thicker sheets of copper may be "stuck" together by resistance welding, but this is more of a keying action with no actual weld "slug" being formed.

Spot welding of copper is rendered less difficult by plating the copper with tin in order to increase its contact resistance. Nickel and manganese coatings have also been used successfully.

Projection and butt welding of copper are not recommended where design requires a sound weld.

Flash welding of copper is accomplished readily using technique similar to that outlined for aluminum.

Resistance welding of copper alloys is accomplished with a difficulty directly proportional to their electrical conductivity as indicated in Table 2. Thus Silicon Bronze and Nickel Silver are most easily spot and seam welded, silicon being the most effective of the elements for increasing weldability of the copper alloys.

Seam welding of copper alloys requires lower pressures than those indicated in the spot welding chart of Table 2. Best strength values have been obtained at pressures of 50 to 80% of those normally used on low-carbon steel.

Projection and butt welding of the copper alloys is not considered reliable, although precise control of weld set-up and special projection design to compensate for extreme material weakness at welding heat may give satisfactory results.

Flash welding is best done at a high rate of acceleration, short flash time, and short duration of current following upset, similar to procedure with Nickel.

Welding of Dissimilar Materials

In order to obtain a true weld between two unlike materials, it is necessary that:

1. Both metals will combine to form an alloy.
2. Melting points are not widely separated.

If extreme variations of electrical conductivity or weldment mass are present, it will be necessary to control the heat generated in or transmitted to the separate weldments by:

1. Use of an electrode of low conductivity to increase heat in weldment having high conductivity.
2. Use of smaller electrode to concentrate current in high conductivity weldment (spot or seam welding).
3. Design of projections, reducing flow of heat away from weld point in high conductivity or large mass weldment (projection welding).
4. Use of short weld time, limiting heat losses.

These expedients are unnecessary in flash welding because of the intense localized heating created at the weld line by the flash.

—FLASH WELDING BOOK—

Beginning with this issue and continuing in the next two issues there will be published a translation of the most comprehensive book yet available on Flash Welding. The book will be reprinted as a separate pamphlet and will be available about Nov. 15th. Orders may be placed now and up to Nov. 1st. Price $1.00. A limited edition will be printed. Fulfillment of orders placed after Nov. 1st not guaranteed.

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Shop Notes on Welding Stainless Steel*

By Vincent J. Shanahan†

MAINTENANCE, repair and fabricating shops will utilize increasing amounts of stainless steel in the future. Such shops do not always possess precision welding equipment as Unionmelt machines and elaborate spot-welding jigs or other devices so frequently referred to in the literature on stainless steel. What shop foremen and welders can use is a practical summary data for stainless fabrication.

What type of rod should be used? What size? How much will we need? Will the work distort? What does heat do to stainless steels? These are the questions discussed in the five sections of this article.

1. Comparison of welding carbon steel and stainless steel.
2. Effect of heat on stainless steel.
3. Selection of the type of electrodes.
4. Selection of size and quantity of electrodes.
5. Operating instructions.

I. Comparison of Welding Carbon Steel and Stainless Steel

Many welders who have successfully fabricated straight carbon steel are reluctant to weld stainless steel and have mistaken ideas of the difficulty of working stainless. First, it should be made clear that the 18–8 stainless type can be very readily welded by the metallic arc and the acetylene processes.

To obtain clean, ductile, uniform welds, we should know the general classification of stainless in comparison with carbon steels.

If carbon steel is represented by the number 100 for each of the following classifications, we have these approximate values for 18–8 stainless:

Specific electrical resistance	640
Melting point	95
Specific heat resistance	110
Thermal conductivity	33
Coefficient of expansion	145

Briefly, we see that 18–8 has six times the resistance to electrical current and melts at lower temperature, conducts heat only one-third as fast and expands half again as much. This indicates that allowances must be made for expansion and contraction, and that holding fixtures would be desirable in many cases, and that chill bars and similar devices should be carefully considered in setting up the job.

The fact that the electrical resistance of 18–8 stainless is about six times that of mild steel means that lower currents can be used. The tables in "Operating Instructions" will indicate these voltages. Straight chrome grades of stainless expand about 10% less than carbon steel and hence welded structures can be designed in almost the same manner as mild steel. The low thermal conductivity (approximately one-half mild steel) may cause slight warpage in gages and suitable jigs are advisable. The electrical resistance of straight chromium grades is from three to six times that of mild steel with only a slightly lower melting point. The straight chromium stainless steels may be divided into two groups; those hardenable by heat treatment, and those non-hardenable. The latter group (Types 442, 443 and 446) contain 18% and over of chromium and heat tends to cause embrittlement, which cannot be entirely relieved by subsequent heat treatment. This grade is not generally used in applications subject to vibration, shocks or deformations.

The straight chromium stainless steels from 10–18% (Types 410, 420, 430 and 440) are hardenable and air-hardened in cooling from the welding temperatures. Heat treating and annealing from 1350 to 1400° F. will increase toughness and ductility of the weld area.

II. Effects of Heat on Stainless Steels

The fundamental principle of all welding, whether by electric arc or by flame, is to apply sufficient controlled heat at a given point to melt and fuse the section to be welded. The above principle holds true, whether a filler rod is used or not.

Heat, then, is the most important factor, not only because of the distortion of stainless under temperature, but also because high temperatures definitely affect the ultimate corrosion resistance or physical properties of the stainless. Certain techniques and alloys have been developed to counteract the heat of welding.

Let us consider the chromium-nickel stainless steels first.

In welding 18–8 steels, the area on both sides of the weld is subject to varying degrees of temperature, ranging from approximately 2900° F. at the weld to room temperature at the extremities of the sheet or plate on a large piece. In the heated area there is a band at which temperatures between 900 and 1600° F. exist for a period of time.

Within these temperatures the carbon in the steel combines with the chromium to form chromium carbides along the grain boundaries. This process is called "carbide precipitation." Such an area is more subject to corrosion than the base metal, because the chromium content of steel at that point is lowered by the precipitation.

Several things can affect the degree of formation of the carbides. If a low-carbon stainless (Type 304) is used, the precipitation is less. A low-carbon (Type 308) electrode is also of great assistance in controlling the carbides. The elements columbium and titanium (Types 347 and 321) may be added to stabilize the stainless and to prevent the formation of chromium carbide. The length of time the steel is held between the critical range of 900 to 1600° F. has a direct and harmful bearing on the amount of carbides formed. The ratio of the alloy content to the carbon content affects this precipitation.

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* Scheduled for Twenty-Sixth Annual Meeting, A.W.S., October 1945.

† Electric Steel Foundry Company, Portland, Ore.

Iron and Steel Institute Type Numbers for Stainless Steels

Steel Type No.	Carbon	Chrome	Nickel	Other Elements	For Welding Use Electrode Type Numbers
302	0.08-0.20	18.00-20.00	8.00-10.00	Mn 1.25	308
303	0.20 max.	18.00-20.00	8.00-10.00	S or Se 0.07 min., or Mo 0.80 max.	308
304	0.08 max.	18.00-20.00	8.00-10.00	Mn 2.00 max.	308
309	0.20 max.	22.00-26.00	12.00-14.00	.....	309
310	0.25 max.	25.00-26.00	19.00-21.00	.....	310
316	0.10 max.	16.00-18.00	14.00 max.	Mo 2.00-3.00	316
321	0.10 max.	17.00-20.00	7.00-10.00	Ti (min) 4 x carbon	347
330	0.25 max.	14.00-16.00	33.00-36.00	.....	330
347	0.10 max.	17.00-20.00	8.00-12.00	Cb (min.) 10 × Carbon	347
410	0.15 max.	10.00-14.00	.....		410
416	0.15 max.	12.00-14.00	.....	S or Se 0.07 min., or Mo 0.60 max.	410
420	Over 15	12.00-14.00	.....	.....	430
430	0.12 max.	14.00-18.00	.....	S or Se .07 min., mo. 60 max.	430
440	Over 0.12	14.00-18.00	.....	.....	446
502	0.10 max.	4.00- 6.00	.....	Mo. 50 max., Cb. 50 max.	501

Heat treatment of the entire welded article is the best way of eliminating the carbides, assuming that a stabilized stainless is not being used. After the carbides have formed at some point over 900° they cannot be reabsorbed in the solid austenitic condition of the steel until an annealing temperature of 1800–1900° F. has been reached. On cooling from these higher temperatures either in air or water carbides are again dissolved into "solution" in the metal. There are, to be sure, many mildly corrosive or sanitary applications where the presence of carbides is not harmful and no effort need be made to control them.

Carbide precipitation can be lessened by the shooting of a stream of cool water over the weld after laying each rod of weld. If the plate or sheet is thick enough to require an inside and outside weld, the last weld to be made can be cooled by spraying water on the opposite side of the seam. However, more desired results can be attained by spraying water on each side of the seam as it is being welded.

Caution must be taken not to get water into the weld crater at the time of welding. This is a very practical application on units that are too large for heat-treating ovens.

Since many fabricated sections cannot be readily heat treated, metallurgical research developed the use of two other alloying metals, titanium and columbium, which prevent the formation of carbides when added to the chromium nickel steel in fixed proportions to the carbon content. The most common of these stabilized steels are Type 321 (titanium) and Type 347 (columbium). Columbium may also be added to other chromium steels (Type 309 Cb and Type 310 Cb) in order to prevent carbides.

Titanium is never used in stabilizing electrodes because the element oxidizes almost completely at welding temperatures. Columbium is always the stabilizing element in 18–8 stainless electrodes.

The straight chromium grades do not lose corrosion resistance as a result of heat of welding. They are stable at all temperatures. The physical properties of these steels are decidedly affected by heat, and they are as a group more difficult to weld. Heat enlarges the grain size of the chromium steels.

In general, those under 18% chromium (Types 410, 420, 430 and 440) air harden after welding, lose ductility and thus become brittle. The strains which are created by the heat of welding can be so great as to cause the metal to crack, usually in the area adjacent to the weld. If the metal section can be preheated up to a range of 350 to 400° F. before welding, the temperature changes are not so abrupt, but are spread over a larger area stresses a better opportunity to relieve or spread themselves. Postheating up to temperatures of 1200 to 1400° F. may be useful in some cases.

III. Selection of the Type of Electrodes

In general the type of electrodes used should be the same as the type of metal to be welded. The analysis of the rod is usually of higher alloy composition in order to insure a weld equal in analysis to the parent metal. The coating of electrodes provides a flux which shields the molten steel from the arc, prevents oxidation of the chromium, helps to stabilize the arc and gives a more corrosion-resistant weld. In general a higher alloy content is used in the electrodes rather than in the material being welded. For example 18-8 electrodes are frequently being used to weld straight chromium steels. Type 302 can be quite successfully welded with Type 308 electrodes although Type 347 would be even better for the more severe corrosive applications. The use of electrodes with a different alloy content than the material to be welded should be carefully checked to determine if the corrosive conditions to be encountered would permit such a change.

Analysis of Electrodes

Type	Carbon	Chromium	Nickel	Molybdenum
308	0.07% max.	19% min.	9% min.	Mn 2.00
309	0.25% max.	25% min.	12% min.	
310	0.25% max.	25% min.	20% min.	
316	0.10% max.	18% min.	8% min.	2–4% Molybdenum
330	0.25% max.	15% min.	35% min.	
347	0.07% max.	18% min.	8% min.	with Columbium Cb 10 × Carbon
410	0.12% max.	12% min.	.....	
430	0.12% max.	16% min.	.....	
446	0.35% max.	23% min.	.....	
501	0.10% max.	.....	.....	2% with Molybdenum

IV. Selection of Sizes and Quantity of Electrodes

To assist the welder to determine the size and quantity of electrodes needed for a given job, the following

tables can be used as a general guide. Naturally special conditions may alter these figures somewhat.

Butt Welds

Plate Size	Rod Size, In.	Lb. Rods per Ft. Weld	Current, Amp.	Arc, Volts
30-22 gage	1/32	0.04	8- 15	18
18-20 gage	3/64	0.06	15- 25	20
14-16 gage	1/16	0.10	40- 50	22
1/8 In.	3/32	0.18	80-100	24
3/16 In.	1/8	0.30	110-130	26
1/4 In.	5/32	0.50	150-170	27
5/16 in.	3/16	0.75	180-200	28
3/8 In.	1/4	1.20	225-250	30
1/2 In.	5/32-1/4	2.75	225-250	30
1 In.	3/16-1/4	4.50	225-250	30

Fillet Welds

Plate Size	Rod Size, In.	Lb. Rods per Ft. Weld	Current, Amp.	Arc, Volts
30-22 gage	1/32	0.03	7- 12	17
18-20 gage	3/64	0.05	12- 20	19
14-16 gage	3/64	0.08	15- 25	20
1/8 In.	1/16	0.16	35- 45	21
3/16 In.	3/32	0.27	70- 90	23
1/4 In.	1/8	0.45	100-120	25
5/16 In.	5/32	0.65	140-160	26
3/8 In.	3/16	1.10	170-190	27
1/2 In.	1/4	2.00	220-240	29
1 In.	3/16-1/4	4.10	220-240	29

Coated electrodes must be kept dry. This can be attained by heating rod storage room or cabinet to about 80 or 90° F. Poor welds result in a damp coating. Damp coating will crack and drop off while welding and the bare electrode must then be discarded. Standard lengths of rod are 14 to 15 in. for 1/8 to 1/4 in. diameter and 9 in. for 1/32 to 3/32 in. Center grip electrodes are 18 in. long.

V. Operating Instructions

The following practical rules for stainless welding conscientiously followed, should improve both quality and production.

1. First clean the work to be welded. Use stainless wire brushes and stainless steel wool. However, under wartime restriction this can be substituted for clean wire brushes. Keep the welding benches and fixtures free from all dirt of any type.

2. Align all edges very exactly. Wherever the work will permit, holding fixtures should be used. If jigs are not feasible or economical, tack welds are advised. The tacking should be on the opposite side of the weld if possible. The size and number of tacks should vary with the type of work and weight of material, bearing in mind that the tack should fuse in with final weld or the tack should be ground or chipped out depending on both the quality of tack and quality of work desired. Chill bars, placed on the weld to convey heat away quickly, will help to minimize the carbide formation. Copper chills are preferred.

3. Reverse polarity is generally used to weld stainless, the electrode being positive and the work negative.

4. A short arc produces the cleanest weld with the least splatter and best penetration. Do not let the arc become so short that the coating touches the mletal

5. To start, strike the arc just ahead of the crater, then move back slowly to remelt the crater.

6. Advance at a rate which will completely fill all undercut, and at a rate which will not allow any slag inclusion.

7. Clean off each weld bead thoroughly before a new one is laid. Any oxides or residues of flux on the steel will be focal points of weakness, both physically and chemically. Electrolysis may start within such pockets of impurities.

8. Avoid weaving the weld unless necessary on very wide beads. The motion tends to make slag inclusions. However, weaving can be accomplished after a little experience but caution is very necessary.

9. One pass can be used to weld thicknesses up to 3/16 in. Over that multiple passes are superior.

10. Renewing the electrode permits the metal to cool and solidify. It is very necessary that the old crater should be clean before striking the new arc.

11. Clean the welded surface to resist corrosion, as well as improve appearance. The heat discoloration can be removed by pickling or grinding. Weld spatters must be chipped off with a chisel or sharp tool. They are the starting point of corrosion and destroy appearance.

12. To shear or punch stainless steel requires about one and one-half or two times the capacity of mild steel. To prepare welding edges, planing is recommended, however, if this type of preparation is not attainable, grinding may be used. A caution must be exercised in grinding to keep the edges straight or parallel with each other, where neither type of preparation available or practical because of conditions. One hundred per cent penetration can be obtained by welding in a slight vertical weld uphand on metal up to eight gages. On gages lighter than 14 gage or 16 gage no edge preparation is necessary, but the larger rods, more heat and speed are obtained by welding on a slight vertical position down hand.

Oxyacetylene Welding

Oxyacetylene welding will be referred to only briefly, since its greatest range of usefulness is in welding 20-gage and lighter stainless steel. The corrosion resistance, strength and appearance of the weld are best when a slightly reducing flame is used. A reducing flame (slightly excess of acetylene) is characterized by a bright blue cone inside the flame with a slight feathering beyond the cone. An oxidizing flame should and can be avoided; being easily recognized as the smallest flame in over-all proportions. Uncoated or bare rods are commonly employed. A thin paste of flux may be brushed on the rod as the operator desires.

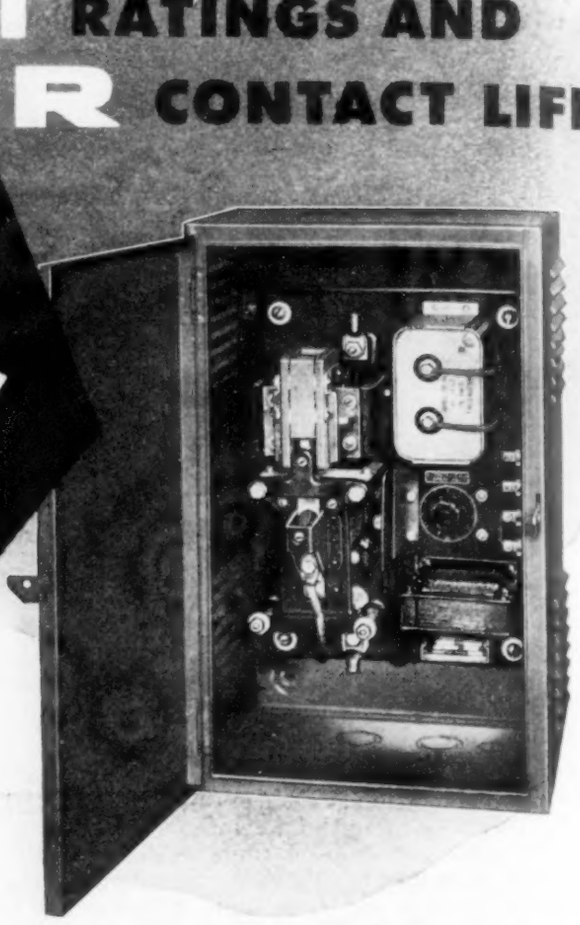
The objective of this article has been primarily to assemble some practical information for the shop welder on the fabrication of stainless steel. But this article is confined largely to "cause" and "effect." There is much more that could be added, most of it is highly technical in nature as in the case of Unionmelt, atomic hydrogen, Heli-arc and resistance welding.

Atomic hydrogen welding has come into the field of stainless steel welding which will be developed for smaller shop use. Atomic hydrogen welding can attain such a high degree of proficient fusion that it defies any physical or chemical analysis to detect the weld area. This type of welding can be used either with or without the filler rod.

EDITOR'S NOTE: Discussion of this Annual Meeting Paper should be submitted not later than Sept. 10, 1945

FOR HIGHER RATINGS AND LONGER CONTACT LIFE

SQUARE D SYNCRO-BREAK RESISTANCE WELDER CONTACTORS



Arcing is eliminated at the contact tips of *SYNCRO-BREAK* contactors by separately energizing the magnet "shading coil" from a transformer and rheostat circuit. Correct rheostat adjustment causes the contacts to part as the alternating current wave approaches zero. Thus, the contactor interrupts zero current and no arc is drawn.

Elimination of arc heat at contacts increases allowable ratings and contact tip deterioration is reduced substantially. Rheostat adjustment is not critical and synchronization remains stable over long periods of usage.

Among the important mechanical design features which assure long, trouble-free service are: Hardened, knife-edge bearings for long life without lubrication. Solid contact supports to conduct away heat and relieve contact studs from impact strain. Low inertia moving parts and short contact gap, permitting consistent high-speed operation.

FOR FULLY AUTOMATIC CONTROL OF RESISTANCE WELDING MACHINES

Use Safront Weld or Sequence Timers with SYNCRO-BREAK Contactors or HIGH-SPEED Contactors

Available in 18 NEMA standard types with separate pneumatic timing relays for each step of the welding cycle. All electrically energized parts are placed behind a protective panel. Calibrated timer dials are adjusted from the front.

Notice attractive new flat-door cabinet construction which harmonizes with Safront timers. This design allows more interior wiring space without increasing overall outside dimensions. Syncro-Break contactors are single pole only.

Available in either single or double pole, employing the same contactor construction as the Syncro-Break. High-Speed contactors without the synchronizing circuits are applied where operation is less frequent and loads are lighter.

SQUARE D COMPANY

DETROIT • MILWAUKEE • LOS ANGELES

Tentative Specifications for

IRON AND STEEL ARC-WELDING ELECTRODES[1]

Serial Designation: A 233 – 45 T

ISSUED, 1940; REVISED, 1942, 1943, 1945.[2]

These Tentative Specifications have been approved by the sponsoring committee and accepted by the Cooperating Societies in accordance with established procedures, for use pending adoption as standard. Suggestions for revisions should be addressed to the Headquarters of the A.S.T.M., 260 S. Broad St., Philadelphia 2, Pa., or of the A.W.S., 33 W. 39th St., New York 18, N. Y.

These specifications were prepared jointly by the American Welding Society and the American Society for Testing Materials.

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Scope

1. (*a*) These specifications cover light-coated and heavy-covered metal arc-welding electrodes for the welding of carbon and low alloy steels of weldable quality.

NOTE.—In connection with the welding of low alloy steels the requirements of these specifications pertain to the tensile strength and elongation of the deposited metal and not to high- or low-temperature characteristics, creep properties, or corrosion resistance.

(*b*) The electrodes are classified on the basis of ultimate tensile strength and usability characteristics (see Appendix). Any electrode classified under one classification shall not be classified under any other classification as presented in Table IV.

Manufacture

2. The electrodes may be made by any methods that will yield a product conforming to the requirements of these specifications.

Standard Sizes and Lengths

3. Standard sizes and lengths of electrodes are as shown in the following table. In all cases, standard size refers to the diameter of the core wire.

Standard Sizes, Diameter of Core Wire, in.	Standard Lengths, in.
$\frac{3}{16}$	9 or 18[a]
$\frac{5}{32}$	12 or 18[a]
$\frac{1}{8}$ and $\frac{5}{32}$	14
$\frac{3}{16}$	14 or 18
$\frac{7}{32}$, $\frac{1}{4}$, $\frac{5}{16}$, and $\frac{3}{8}$	18

[a] In the case of 18-in. lengths of $\frac{1}{4}$ and $\frac{5}{16}$-in. electrodes, center gripping of the electrodes is standard. In all other cases, end gripping is standard.

Chemical Composition

4. The electrodes shall not be required to comply with any limitations

[1] Under the standardization procedure of the two Societies, these specifications are under the jurisdiction of the A.W.S.-A.S.T.M. Joint Committee on Filler Metal.

[2] Latest revision accepted by A.S.T.M. Committee E-10 on Standards, May 19, 1945; approved by A.W.S. Board of Directors, April 19, 1945.

These specifications which comprise a portion of the former Tentative Specifications for Iron and Steel Filler Metal (Arc-Welding Electrodes and Gas-Welding Rods (A 205 – 37 T)) were published as tentative from 1937 to 1940.

Electrode			All-Weld-Metal Tension Test[a] (See Note 1)	Usability Tests[b]	
Classification Number	Diameter, in.	Current and Polarity		Guided-Bend Test[c] (See Notes 2 and 3)	Fillet-Weld Test[d] (See Notes 2 and 3)
E4510	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	not specified	not required F not required not required	not required not required not required not required	not required not required not required not required
E4520	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	not specified	not required F not required not required	not required not required not required not required	not required not required not required not required
E6010 E7010	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. reversed polarity (electrode positive)	not required F F F	not required V and OH F F	not required V and OH H not required
E6011 E7011	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	a.c. and d.c. reversed polarity (electrode positive)	not required F F F	not required V and OH F F	not required V and OH H not required
E6012 E7012	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. straight polarity (electrode negative) and a.c.	not required F F F	not required V and OH F F	not required V and OH H not required
E6013	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	a.c. and d.c. straight polarity (electrode negative)	not required F F F	not required V and OH F not required	not required V and OH H not required
E6020 E7020	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. straight polarity (electrode negative) or a.c. for H-Fillets; d.c. either polarity or a.c. for flat position welding	not required F F F	not required F F F	not required H H not required
E6030 E7030	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. either polarity or a.c.	not required F F F	not required F F F	not required not required not required not required
E8010 E9010 E10010	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. reversed polarity (electrode positive)	not required F F F	not required not required not required not required	not required not required not required not required
E8011 E9011 E10011	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	a.c. and d.c. reversed polarity (electrode positive)	not required F F F	not required not required not required not required	not required not required not required not required
E8012 E9012 E10012	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	a.c. and d.c. straight polarity (electrode negative)	not required F F F	not required not required not required not required	not required not required not required not required
E8020 E9020 E10020	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c. straight polarity (electrode negative) or a.c. for H-Fillets; d.c. either polarity or a.c. for flat position welding	not required F F F	not required not required not required not required	not required not required not required not required
E8030 E9030 E10030	$\frac{1}{16}$ to $\frac{1}{8}$, incl. $\frac{5}{32}$ and $\frac{3}{16}$ $\frac{7}{32}$ and $\frac{1}{4}$ $\frac{5}{16}$ and $\frac{3}{8}$	d.c either polarity or a.c.	not required F F F	not required not required not required not required	not required not required not required not required

[a] See Section 6 and Table II.
[b] See Section 7
[c] See Section 8.
[d] See Section 9 and Table III.

NOTE 1.—Where both the stress-relieved and non-stress-relieved conditions are shown in Table II, "Minimum Tensile Strength and Ductility Requirements for All-Weld-Metal Tension Tests," for a classification of electrodes, the all-weld-metal-tension tests shall be performed on both stress-relieved and non-stress-relieved test specimens.

NOTE 2.—For the guided-bend and fillet-weld tests, the steel for the test assembly shall conform to either of the specifications listed in Section 5 (*b*). For testing electrodes of the E6010, E6011, E7010, and E7011 classifications, one of the plates and backing strip of the guided-bend test assembly, and both plates of the fillet-weld test assembly shall be galvanized after edge preparation with a minimum coating of 2 oz. per sq. ft.

NOTE 3.—No stress-relieving shall be performed on guided-bend test assemblies or on the specimens removed therefrom.

on the chemistry of electrode or of deposited metal.

General Test Requirements

5. (*a*) To be classified, electrodes shall meet the requirements of the all-weld-metal tension test, guided-bend test, and fillet-weld test prescribed in Sections 6, 8, and 9, respectively, for each size in accordance with the requirements prescribed in Table I.

(*b*) For testing electrodes of the E45, E60, and E70 series of classifications, the steel to be used for test plates shall conform to one of the following specifications of the American Society for Testing Materials:

(*1*) Standard Specifications for Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels (A.S.T.M. Designation: A 70).[3]

(*2*) Standard Specifications for Steel for Bridges and Buildings (A.S.T.M. Designation: A 7),[3] open-hearth or electric-furnace steel.

(*c*) For testing electrodes of the E80, E90, and E100 series of classifications, the steel to be used for test plates shall conform to one of the following specifications of the American Society for Testing Materials, or shall be a similar steel containing not over 0.30 per cent carbon and having a minimum tensile strength of 75,000 psi.:

(*1*) Standard Specifications for Low-Carbon Nickel-Steel Plates for Boilers and Other Pressure Vessels (A.S.T.M. Designation: A 203),[3] grade C.

(*2*) Standard Specifications for Molybdenum-Steel Plates for Boilers and Other Pressure Vessels (A.S.T.M. Designation: A 204),[3] grade C.

All-Weld-Metal Tension Test

6. (*a*) Tension tests shall be made as prescribed in Paragraphs (*b*) to (*h*), using the types of current (and polarity if d.c.) for each size and classification of electrode as shown in Table I. Where requirements for both the stress-relieved and non-stress-relieved conditions are specified in Table II for a classification of electrodes, the all-weld-metal tension test shall be performed on both stress-relieved and non-stress-relieved test specimens.

(*b*) For electrodes smaller than $\frac{5}{32}$ in., the all-weld-metal tension test is not practical and the strength of these sizes shall be judged by the all-weld-metal tension test of $\frac{5}{32}$-in. electrodes of the same classification.

(*c*) For electrodes $\frac{5}{32}$ in. and larger a test plate shall be prepared as shown in Fig. 1. The plate shall be insulated from the welding bench by $\frac{1}{2}$ in. of asbestos during welding. After the joint has been tacked, the assembly shall be heated in boiling water for 5 min. prior to welding. The work shall be done in the flat position and in an ambient temperature of not less than 60 F. Weaving shall be the full width of the groove except for the last layer which shall be deposited in two passes.

(*d*) In testing electrodes of the E45, E60, and E70 series of classifications, after depositing each pass, the assembly shall be left on the asbestos to cool in still air for 10 min. and then immersed in boiling water for 5 min. Each subsequent pass shall be deposited immediately after removal from boiling water. After the last pass, the assembly shall be removed from boiling water after the 5-min. period.

(*e*) In testing electrodes of the E80, E90, and E100 series of classifications, after depositing each pass, the assembly shall be left on the asbestos to cool in still air to a temperature below 212 F. before immersing it in boiling water for 5 min. (Note). Each subsequent pass shall be deposited immediately after removal from boiling water. After the last pass, the assembly shall be removed from the boiling water after the 5-min. period.

TABLE II.—MINIMUM TENSILE STRENGTH AND DUCTILITY REQUIREMENTS FOR ALL-WELD-METAL-TENSION TEST.

Electrode Classification Number	Treatment of Welded Specimen[a]	Tension Test Requirements of Material Deposited from $\frac{1}{4}$ to $\frac{5}{16}$-in. incl., Electrodes[b]		
		Tensile Strength, min., psi.	Yield Point, min., psi.	Elongation in 2 in., min., per cent
E4510	NSR	45 000	not specified	5
E4520	NSR	45 000	not specified	5
E6010	SR	60 000	47 000	27
	NSR	62 000	52 000	22
E6011	SR	60 000	47 000	27
	NSR	62 000	52 000	22
E6012	SR	60 000	47 000	22
	NSR	62 000	52 000	17
E6013	SR	60 000	47 000	22
	NSR	62 000	52 000	17
E6020	SR	60 000	47 000	30
	NSR	62 000	52 000	25
E6030	SR	60 000	47 000	30
	NSR	62 000	52 000	25
E7010	SR	70 000	57 000	22
E7011	SR	70 000	57 000	22
E7012	SR	70 000	57 000	18
E7020	SR	70 000	57 000	25
E7030	SR	70 000	57 000	25
E8010	SR	80 000	67 000	19
E8011	SR	80 000	67 000	19
E8012	SR	80 000	67 000	16
E8020	SR	80 000	67 000	22
E8030	SR	80 000	67 000	22
E9010	SR	90 000	77 000	17
E9011	SR	90 000	77 000	17
E9012	SR	90 000	77 000	14
E9020	SR	90 000	77 000	20
E9030	SR	90 000	77 000	20
E10010	SR	100 000	87 000	16
E10011	SR	100 000	87 000	16
E10012	SR	100 000	87 000	13
E10020	SR	100 000	87 000	18
E10030	SR	100 000	87 000	18

[a] The abbreviations SR and NSR signify stress-relieved and non-stress-relieved, respectively. Stress-relieving shall be within the range of 1150 ± 25 F. for 1 hr. per inch of thickness. Specimens shall be heated in a suitable furnace at the rate of 300 to 350 F. per hr. until a temperature of 1150 ± 25 F. has been attained. After this temperature has been reached, it shall be maintained for 1 hr. for each inch or fraction thereof of the maximum thickness of the section. The specimens shall be cooled at the same rate specified for heating and may be removed from the furnace when the temperature of the plates has reached 300 F.

[b] The tension test requirements of material deposited from $\frac{1}{4}$-in. electrodes shall be the same as that indicated for $\frac{5}{16}$ to $\frac{3}{8}$-in. electrodes, except that the tensile strength and yield point shall be 95 per cent of that prescribed in Table II.

NOTE.—This immersion should not quench the assembly—the boiling water is intended simply as a preheat.

(*f*) If it is necessary to interrupt the [illegible] accordance with that figure. Any convenient means may be used for moving

pass sequence prescribed in Paragraphs (*d*) and (*e*) the assembly shall be removed from the boiling water after a 5-min. period and allowed to cool in still air at room temperature. When ready to resume work, the assembly shall be preheated in boiling water for a period of 5 min.

(*g*) Two all-weld-metal tension test specimens shall be machined from each finished test plate as shown in Fig. 1, and shall conform to the requirements as to tensile properties prescribed in Table II.

(*h*) If either specimen fails, another test plate shall be welded and both specimens shall conform to the requirements as to tensile properties prescribed in Table II.

Usability Tests

7. (*a*) The usability characteristics of an electrode shall be determined by the guided-bend test and fillet-weld test prescribed in Sections 8 and 9, respectively.

(*b*) For testing electrodes of the E6010, E6011, E7010, and E7011 series of classifications, one of the test plates and the backing strip for the guided-bend test and both plates for the fillet-weld test, shall be galvanized after edge preparation with a minimum zinc coating of 2 oz. per sq. ft.

Guided-Bend Test (Usability Test)

8. (*a*) The guided-bend test as described in Paragraphs (*b*) to (*f*), shall be required for electrodes of the E60 and E70 series of classifications only. Where a classification of electrode permits its use with more than one type of current (or polarity), it shall be tested using each type of current (and polarity). The required test plates shall be so restrained or preset that warping due to welding will not cause the finished test plate to be out of line by more than 5 deg.

[illegible] if any, directed toward the gap. The two members of the jig shall be forced

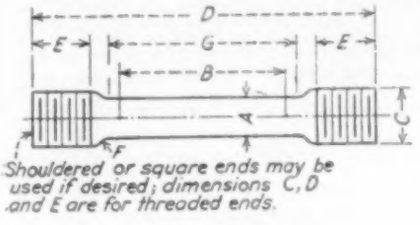
[3] 1944 Book of A.S.T.M. Standards, Part I.

using the types of current (and polarity if d.c.) for each size and classification of electrode as shown in Table I. Where

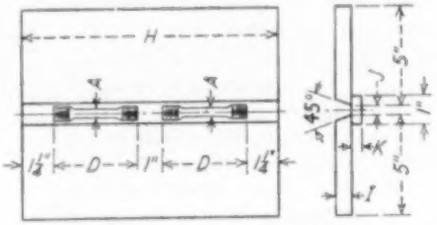
* 1944 Book of A.S.T.M. Standards, Part I.

removal from boiling water. After the last pass, the assembly shall be removed from the boiling water after the 5-min. period.

Electrode Size, in.	Test Plate Thickness, in. I	Type of Layers for Testing Electrodes	Diameter of Tension Test Specimen, in. A	Dimensions of Test Plate and Tension Test Specimen, in. B	C	D	E	F	G	H	J	K
5/32	3/4	* Each Layer or Pass not to Exceed 1/8 in. in Thickness.	0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4
3/16	3/4		0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4
1/4	3/4		0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4
5/16	1		0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4
3/8	1 1/4		0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4
7/16	1 1/2		0.500 ± 0.01	2	3/4	4 1/2	3/4	3/8	2 1/2	12	1/2	3/4



Tension Test Specimen.



Test Plate Showing Location of Test Specimens.

FIG. 1.—Requirements for Preparation of All-Weld-Metal Tension Test Specimens.

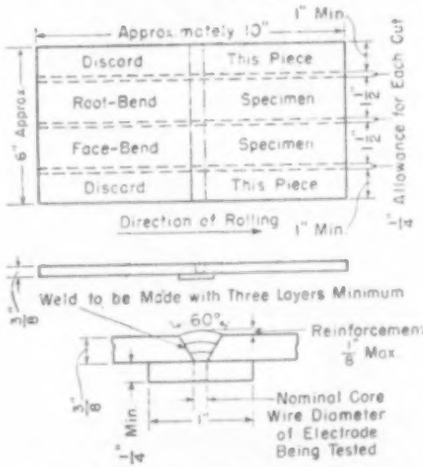


FIG. 2.—Test Joint for Guided Bend Test.

NOTE.—One plate and backing strip to be galvanized after edge preparation for testing electrodes of the E6010, E6011, E7010, and E7011 classifications (See Section 7 (b)).

(*b*) For electrodes 3/32 and 3/16 in. in diameter a test joint conforming to the requirements of Fig. 2 shall be prepared in the welding positions and using the types of current (and polarity if d.c.) shown in Table I. The first pass shall be started with the test assembly at a temperature between 60 and 100 F. No stress-relieving shall be performed on the test assembly nor on the specimens removed therefrom. From each completed test assembly one face-bend and one root-bend specimen shall be removed as shown in Fig. 2 and prepared for testing as shown in Fig. 3.

(*c*) For electrodes 7/32 to 3/8 in., inclusive, in diameter, a test joint conforming to the requirements of Fig. 4 shall be prepared in the welding positions and using the types of current (and polarity if d.c.) shown in Table I. The first pass shall be started with the test assembly at a temperature between 60 and 100 F. No stress-relieving shall be performed on the test assembly nor on the specimens removed therefrom. From each completed test assembly two side-bend specimens shall be removed as shown in Fig. 4 and prepared for testing as shown in Fig. 5.

(*d*) Each of the face-, root- and side-bend specimens shall be bent in a jig having the working contour shown in

the assembly—the boiling water is intended simply as a preheat.

(*f*) If it is necessary to interrupt the

accordance with that figure. Any convenient means may be used for moving the plunger member with relation to the die member. The specimen shall be placed on the die member with the weld

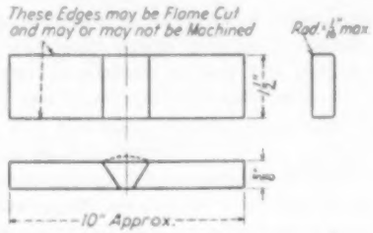


FIG. 3.—Face- and Root-Bend Test Specimens.

NOTE.—Weld reinforcement and backing strip shall be removed flush with the surface of the specimen. Machining or grinding shall be done lengthwise on the specimen. The surface of the specimen to be tested shall be finely machined or ground.

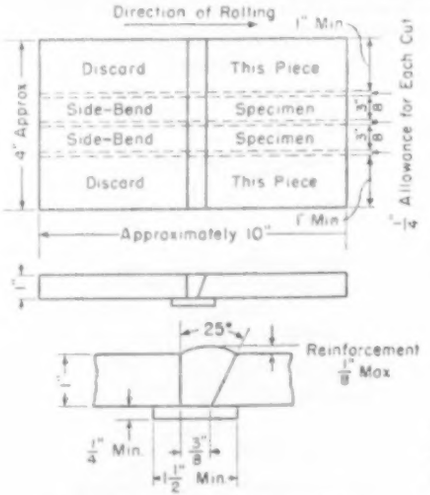


FIG. 4.—Test Joint for Side-Bend Test.

NOTE.—Beveled plate and backing strip to be galvanized after edge preparation for testing electrodes of E6010, E6011, E7010, and E7011 classifications (See Section 7 (b)).

at mid-span. Face-bend specimens shall be placed with the face of the weld directed toward the gap; root-bend specimens shall be placed with the root of the weld directed toward the gap; side-bend specimens shall be placed with

strained or preset that warping due to welding will not cause the finished test plate to be out of line by more than 5 deg.

if any, directed toward the gap. The two members of the jig shall be forced together until the specimen conforms to a U-shape, and until a wire 3/32 in. in diameter cannot be placed between the specimen and any point on the curvature of the plunger member of the jig. The specimen shall then be removed from the jig.

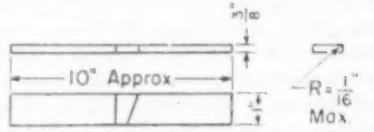


FIG. 5.—Side-Bend Specimen.

NOTE.—Specimens shall be sawed or machined from test joint.

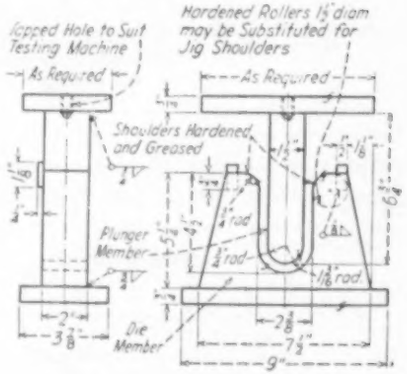


FIG. 6.—Guided-Bend Test Jig.

(*e*) The convex surface of each specimen shall be examined for the appearance of cracks or other open defects. The electrode shall be considered as having failed if a crack or other open defect, exceeding 1/8 in. measured in any direction, is present in either specimen after the bending. Cracks occurring on the corners of the specimen during testing shall not be considered. If either specimen fails another guided-bend test assembly shall be prepared and tested in accordance with Paragraphs (*b*) to (*e*) inclusive.

TABLE III.—REQUIREMENTS FOR PREPARATION OF FILLET-WELD TEST ASSEMBLIES

Electrode Classification Number	Diameter, in.	PLATE SIZE[a]			Position of Welding	Size of Fillet, in.
		Thickness (T)	Width (W)	Length (L)		
E6010 E6011	1/16 to 3/16, incl.	not required				
E7010	5/32	1/4	3	12	V and OH	1/4 max.
	3/16	3/8	3	18	V and OH	1/4 max.
	7/32	3/8	3	18	H	5/16 max.
E7011	1/4	1/2	3	18	H	5/16 max.
	5/16 and 3/8	not required				
E6012	1/16 to 3/16, incl.	not required				
E7012	5/32	1/4	3	12	V and OH	1/4 max.
	3/16	3/8	3	18	V and OH	5/16 max.
	7/32	3/8	3	18	H	1/4 max.
	1/4	1/2	3	18	H	5/16 max.
	5/16 and 3/8	not required				
E6013	1/16 to 3/16, incl.	not required				
	5/32	1/4	3	12	V and OH	1/4 max.
	3/16	3/8	3	18	V and OH	5/16 max.
	7/32	3/8	3	18	H	1/4 max.
	1/4	1/2	3	18	H	5/16 max.
	5/16 and 3/8	not required				
E6020	1/16 to 3/16, incl.	not required				
E7020	5/32	3/8	3	18	H	5/32 min.
	3/16	3/8	3	18	H	3/16 min.
	7/32	3/8	3	18	H	1/4 min.
	1/4	1/2	3	18	H	5/16 min.
	5/16 and 3/8	not required				
E6030 E7030	not required					

[a] See Fig. 7.

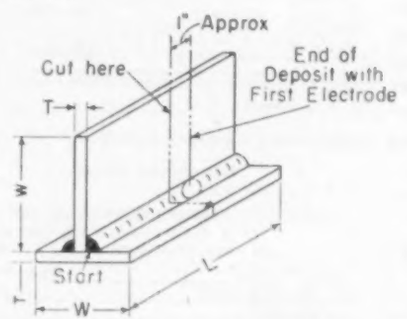


FIG. 7.—Preparation of Fillet-Weld Test.

NOTE 1.—Both plates shall be galvanized after edge preparation for testing electrodes of the E6010, E6011, E7010, and E7011 classifications (See Section 7 (b)).
NOTE 2.—See Table III for values of T, W, and L.

(*f*) Electrodes 1/16 to 1/8 in. inclusive, in diameter need not be tested but shall be judged by the test results of 5/32-in. electrodes of the same classification.

Fillet-Weld Test (Usability Test)

9. (*a*) The fillet-weld test, as described in Paragraphs (*b*) to (*k*), shall be required for electrodes of the E60 and E70 series of classifications only. Where a classification of electrode permits its use with more than one type of current (or polarity), it shall be tested using each type of current (and polarity).

(*b*) A fillet-welded tee-joint assembly as shown in Fig. 7 shall be prepared. The dimensions of the test plates, positions of welding, and sizes of fillet shall be as prescribed in Table III for the particular size and classification of the electrode being tested.

(*c*) In preparing the two plates forming the test assembly, the standing member shall have one edge machined throughout its length so that when it is set upon the base plate, which shall be straight and smooth, there will be intimate contact for the entire length of the joint.

(*d*) A single-pass fillet weld shall be deposited on one side of the joint using the types of current (and polarity if d.c.) prescribed in Table I. When welding in the vertical position is specified, the progression shall be upward. The first electrode used shall be consumed for its full length except for a stub end of not more than 2 in. Additional electrodes, if necessary, shall then be used to complete the weld for the full length of the joint, consuming each electrode completely as stated above—insofar as permitted by the length of the assembly.

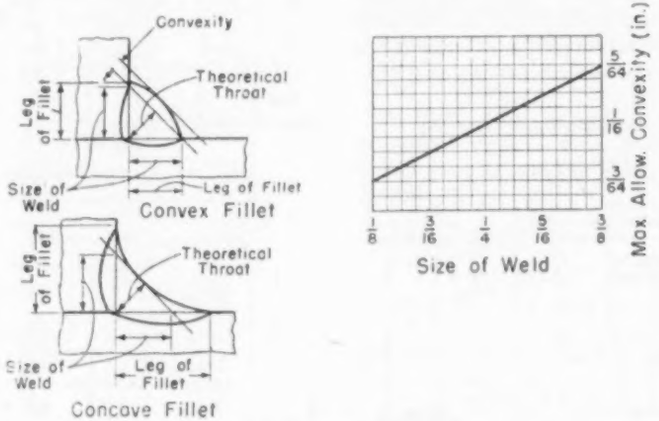


FIG. 8.—Dimensions of Fillet Welds.

NOTE 1.—Size of fillet weld = Leg length of largest inscribed isosceles right triangle.
NOTE 2.—Length of horizontal leg of fillet weld shall not vary more than 1/16 in. from length of vertical leg.
NOTE 3.—Fillet weld size, convexity and leg lengths of fillet welds shall be determined by actual measurement (to nearest 1/64 in.) on a section laid out with scribed lines as shown.

(*e*) After completing the weld on the first side of the joint, the assembly shall be cooled to room temperature (but not less than 60 F.) by any convenient means[4] before commencing to weld on the second side.

(*f*) The fillet weld on the second side of the joint shall be deposited by the same procedure as was the first fillet.

(*g*) Both welds shall be examined to determine that no cracks or other defects have occurred.

(*h*) At a point approximately 1 in. back from the crater end of the deposit made with the first electrode on the first side of the joint the specimen shall be cut. Either face may be polished and etched to permit examination.

(*i*) The polished and etched face shall be scribed as shown in Fig. 8 and the size, the leg lengths and the convexity (of convex fillets) shall be determined to the nearest 1/64 in. by actual measurement.

(*j*) An electrode shall not be deemed satisfactory unless both legs of each fillet weld deposited by it are of equal length within 1/16 in. and unless the convexity is within the maximum allowable limits prescribed by the curve shown in Fig. 8. Each fillet weld shall have penetrated to or beyond the junction of the plate edges; it shall also be free from cracking and reasonably free from undercut, trapped slag and porosity. If the specimen fails, another fillet-weld test assembly shall be prepared and tested in accordance with Paragraphs (*b*) to (*j*), inclusive.

[4] If water is used as the coolant, care should be taken to ascertain that it has been thoroughly removed from the joint.

(*k*) Electrodes 1/4 in. in diameter and

(*b*) Coverings shall be such that they

TABLE IV.—POSITIONS AND CURRENT WITH WHICH ELECTRODES CAN BE USED.

Fillet-Weld Test (Usability Test)

9. (*a*) The fillet-weld test, as described in Paragraphs (*b*) to (*k*), shall be required for electrodes of the E60 and E70 series

(*d*) A single-pass fillet weld shall be deposited on one side of the joint using the types of current (and polarity if d.c.) prescribed in Table I. When weld-

[a] If water is used as the coolant, care should be taken to ascertain that it has been thoroughly removed from the joint.

test assembly shall be prepared and tested in accordance with Paragraphs (*b*) to (*j*), inclusive.

(*k*) Electrodes $\frac{1}{8}$ in. in diameter and smaller, and $\frac{5}{16}$ in. in diameter and larger need not be tested but shall be judged by the test results of electrodes $\frac{5}{32}$ to $\frac{1}{4}$ in., inclusive, in diameter of the same classification.

Permissible Variations in Dimensions

10. (*a*) Heavy covered electrodes for manual welding shall be bare or free from covering for a distance of about 1 in., but not more than $1\frac{1}{4}$ in., for making contact with the holder.

(*b*) The arc end of each electrode shall be sufficiently bare to permit easy striking of the arc, but the length of the bare portion of the arc end, measured from the end to the point where the full cross-section of the coating obtains, shall not exceed one core-wire diameter or in any case be more than $\frac{1}{8}$ in.

(*c*) The diameter of the core wire shall not vary more than plus or minus 0.002 in. from the standard size specified. The length shall not vary more than plus or minus $\frac{1}{4}$ in. from that specified.

(*d*) The covering on heavy covered electrodes of all sizes shall be concentric to the extent that the maximum core-plus-one-covering dimension shall not exceed the minimum core-plus-one-covering dimension by more than 3 per cent. The concentricity shall be measured by any suitable means.

Electrode Coverings

11. (*a*) The coverings shall have sufficient electrical resistance to effectively insulate against a difference of potential of 100 v., 60 cycles a.c.

Workmanship and Finish

12. (*a*) The core wire of all electrodes shall be of uniform quality and free from injurious segregation, oxides, pipe, seams, or other irregularities.

(*b*) Coverings shall be such that they are not readily damaged by ordinary handling and shall be of commercially uniform thickness and shall present a workmanlike appearance. They shall also be free from injurious scabs, blisters, abnormal pockmarks, bruises, or other surface defects.

Packing

13. Electrodes shall be suitably packed, wrapped, boxed, or crated to insure against injury during shipment or storage, as follows:

(*a*) Bundles of 50 lb. net weight,

(*b*) Boxes of 25 or 50 lb. net weight, and

(*c*) Coils or reels of approximately 150 or 200 lb. net weight.

Marking

14. All bundles, boxes, coils, or reels shall be legibly marked with the following information:

(*a*) Classification,

(*b*) Manufacturer's name and trade designation,

(*c*) Standard size and length, (weight instead of length in case of reels and coils), and

(*d*) Guarantee.

Guarantee

15. The manufacturer shall make tests at frequent intervals in accordance with the methods prescribed in these specifications, and shall guarantee that the electrodes in all sizes and classifications conform to these specifications and each container shall be so marked. The manufacturer's responsibility shall be limited to replacement of any electrodes which do not conform to the requirements of these specifications.

TABLE IV.—POSITIONS AND CURRENT WITH WHICH ELECTRODES CAN BE USED.

NOTE.—**Any electrode classified under one classification shall not be classified under any other classification.**

Covering	Electrode Classification Number	Capable of Producing Satisfactory Welds in Positions Shown[a]	General Description
E45 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 45,000 PSI. IN NON-STRESS-RELIEVED CONDITION			
Light Coating	E4510	F, V, OH, H	Sulcoated or light coated electrodes for use in manual welding but sometimes used for machine welding.
	E4520	H-Fillets, F	Light coated electrodes for use with high speed machine welding. May be used for manual welding.
E60 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 60,000 PSI. IN STRESS-RELIEVED CONDITION; 62,000 PSI. IN NON-STRESS-RELIEVED CONDITION.			
Heavy Covering	E6010	F, V, OH, H	For use only with d.c. reversed polarity (electrode positive).
	E6011	F, V, OH, H	For use with a.c. or d.c. reversed polarity (electrode positive).
	E6012	F, V, OH, H	For use with d.c. straight polarity (electrode negative) or a.c.
	E6013	F, V, OH, H	For use with a.c. or d.c. straight polarity (electrode negative) on light gage metal.
	E6020	H-Fillets, F	For use with d.c. straight polarity (electrode negative) or a.c. for horizontal fillet welds and d.c. either polarity or a.c. for flat position welding.
	E6030	F	For use with d.c. either polarity or a.c.
E70 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 70,000 PSI. IN STRESS-RELIEVED CONDITION.			
Heavy Covering	E7010	F, V, OH, H	For use only with d.c. reversed polarity (electrode positive).
	E7011	F, V, OH, H	For use with a.c. or d.c. reversed polarity (electrode positive).
	E7012	F, V, OH, H	For use with d.c. straight polarity (electrode negative) or a.c.
	E7020	H-Fillets, F	For use with d.c. straight polarity (electrode negative) or a.c. for horizontal fillet welds and d.c. either polarity or a.c. for flat position welding.
	E7030	F	For use with d.c. either polarity or a.c.
E80 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 80,000 PSI. IN STRESS-RELIEVED CONDITION.			
Heavy Covering	E8010	F, V, OH, H	For use only with d.c. reversed polarity (electrode positive).
	E8011	F, V, OH, H	For use with a.c. or d.c. reversed polarity (electrode positive).
	E8012	F, V, OH, H	For use with d.c. straight polarity (electrode negative), or a.c.
	E8020	H-Fillets, F	For use with d.c. straight polarity (electrode negative) or a.c. for horizontal fillet welds and d.c. either polarity or a.c. for flat position welding.
	E8030	F	For use with d.c. either polarity or a.c.
E90 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 90,000 PSI. IN STRESS-RELIEVED CONDITION.			
Heavy Covering	E9010	F, V, OH, H	For use only with d.c. reversed polarity (electrode positive).
	E9011	F, V, OH, H	For use with a.c. or d.c. reversed polarity (electrode positive).
	E9012	F, V, OH, H	For use with d.c. straight polarity (electrode negative), or a.c.
	E9020	H-Fillets, F	For use with d.c. straight polarity (electrode negative) or a.c. for horizontal fillet welds and d.c. either polarity or a.c. for flat position welding.
	E9030	F	For use with d.c. either polarity or a.c.

[a] The abbreviations F, H, V, OH, and H-Fillets indicate welding positions (Fig. 9) as follows:
F—Flat, H—Horizontal, V—Vertical, OH—Overhead } For electrodes $\frac{5}{32}$ in. and under
H-Fillets—Horizontal Fillets

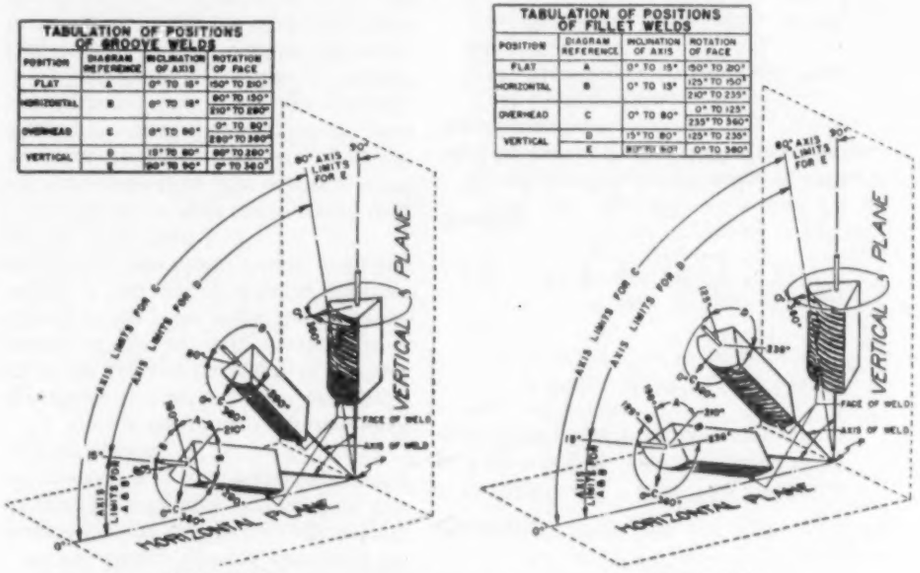
(Continued)

TABLE IV.—POSITIONS AND CURRENT WITH WHICH ELECTRODES CAN BE USED.

NOTE.—**Any electrode classified under one classification shall not be classified under any other classification.**

Covering	Electrode Classification Number	Capable of Producing Satisfactory Welds in Positions Shown[a]	General Description
E100 SERIES.—MINIMUM TENSILE STRENGTH OF DEPOSITED METAL 100,000 PSI. IN STRESS-RELIEVED CONDITION.			
Heavy Covering	E10010	F, V, OH, H	For use only with d.c. reversed polarity (electrode positive).
	E10011	F, V, OH, H	For use with a.c. or d.c. reversed polarity (electrode positive).
	E10012	F, V, OH, H	For use with d.c. straight polarity (electrode negative), or a.c.
	E10020	H-Fillets, F	For use with d.c. straight polarity (electrode negative) or a.c. for horizontal fillet welds and d.c. either polarity or a.c. for flat position welding.
	E10030	F	For use with d.c. either polarity or a.c.

[a] The abbreviations F, H, V, OH, and H-Fillets indicate welding positions (Fig. 9) as follows:
F—Flat, H—Horizontal, V—Vertical, OH—Overhead } For electrodes 5/32 in. and under
H-Fillets—Horizontal Fillets



(a) Groove Welds. (b) Fillet Welds.

The horizontal reference plane is taken to lie always below the weld under consideration.
Inclination of axis is measured from the horizontal reference plane toward the vertical.
Angle of rotation of face is measured from a line perpendicular to the axis of the weld and lying in a vertical plane containing this axis. The reference position (0 deg.) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. The angle of rotation of the face of weld is measured in a clockwise direction from this reference position (0 deg.) when looking toward point "P".

FIG. 9.—Position of Welds.

(See Appendix on page 12)

guided-bend test, which is the same as used for operator and procedure qualification tests. The

characteristics with which the electrode is useful. For example, reference to the E60 group of the

APPENDIX.

GUIDE TO AWS-ASTM CLASSIFICATION OF IRON AND STEEL ARC-WELDING ELECTRODES

PART I.—INTRODUCTION

The possible applications of the metal arc-welding process have been increased tremendously in the past few years by the development of new and improved types of heavy covered electrodes each designed to do specific jobs in the most efficient manner. As a result of these developments the electrode consumer soon found available a vast selection of similar electrodes bearing many trade names, due to the fact that there were a number of manufacturers in the industry, each developing his own line of products. A considerable amount of confusion developed for there was no accepted method of electrode classification. This condition is rapidly being remedied by joint action of the American Welding Society and the American Society for Testing Materials, in the preparation of specifications covering the major types of electrodes now available, such as:

Mild Steel and Low-Alloy Electrodes.
Stainless Steel Electrodes.
Aluminum and Aluminum-Alloy Electrodes.
Nickel and Nickel-Alloy Electrodes.
Copper and Copper-Alloy Electrodes.
Hard Surfacing Electrodes.

The first of these represents the largest volume of electrodes produced and probably the largest number of different covering types applied to a single analysis of core wire. The Tentative Specifications For Iron and Steel Arc-Welding Electrodes (AWS-ASTM Serial Designation: A 233) have become the most widely accepted bases for separating and classifying electrodes that fall within this large group. In these specifications a series of classifications is defined, within which it is possible to place over 90 per cent of the electrodes produced today. The classification numbers established by the specifications are being used very extensively by both the purchasers and the manufacturers instead of the trade names previously used.

In this manner order has been brought out of confusion, for all of the electrodes, regardless of trade names, which meet all of the requirements of any given AWS-ASTM classification may be expected to have major characteristics which are very similar, if not identical. Certain minor differences continue to exist among brands due to differences in production facilities and the usual differences of opinion that exist in any field regarding specific operating characteristics.

Since the electrodes within a given classification are very similar, the purchaser can, after determining the classification best meeting his need, limit his choice of available electrodes to those within that classification.

The AWS-ASTM Specifications A 233 involve only those requirements necessary to define the major characteristics of each type of electrode involved. Test procedures are used in some instances which do not duplicate production conditions; however, this is not peculiar to this series of specifications alone. Many specifications prescribe special procedures when it is necessary to eliminate variables. In the case of Specifications A 233 some may question the use of the so-called "hot water procedure" in the welding of the specified butt joint test assemblies. It is used because it is considered to be the most reliable and easily applied method of obtaining a uniform interpass temperature, regardless of where the work is being done. Control of interpass temperature is necessary since it has an effect upon the mechanical properties obtained from the specimens removed from the test assemblies. The size of test plate, location and number of passes, and stress-relieving procedure are specified for the same reason.

Electrode characteristics which determine its usability for various positions and purposes are: current and voltage range, current characteristics (a.c. or d.c., straight or reversed polarity), weld metal fluidity, mechanical characteristics of deposited weld metal, ability to render a sound weld and satisfactory weld profile. The current range, current characteristics and weld metal fluidity, are determined from experience through use of the electrode. Mechanical characteristics are determined by the all-weld-metal tension test. The ability of an electrode to yield a sound weld is determined by the

FIG. 9.—Position of Welds.

(See Appendix on page 12)

guided-bend test, which is the same as used for operator and procedure qualification tests. The ability of the electrode to make a fillet weld of proper profile is determined by the fillet-weld test. There is no question that any electrode fulfilling the fillet-weld test requirements and possessing the proper mechanical properties as measured by the all-weld-metal tension test will produce the proper fillet shear strength.

Stress-relieving when prescribed in the specifications is for the purpose of developing the fundamental properties of the weld metal unaltered by locked-up stresses. Values obtained from stress-relieved welded specimens are about 5 per cent lower in tensile strength and 10 to 20 per cent higher in elongation than those of non-stress-relieved specimens. The fact that an electrode test requires stress-relief signifies only that it must develop the strength required regardless of stress-relief, and not that stress-relief must always be used in actual work.

The specifications are not expected to measure all of the characteristics of the electrodes falling within a given classification, but it is expected to measure those of major importance. In some instances a particular characteristic is common to a number of classifications and it is not necessary to test each for it. In other instances, characteristics may be of such an intangible nature that no adequate test has been developed to measure them. As a result of this condition, a newcomer in the field may find that a study of these specifications does not give him all the information he needs to determine the classification best fulfilling his particular needs. Appreciating this, the committee responsible for these specifications has prepared a discussion of each classification. It is intended to supplement the information given in the specification and to present a concise summary of those characteristics of the electrodes which are generally considered most important.

The mechanics of the numbering system used in Specifications A 233 is relatively simple. The letter *E* precedes the number designations involving metal-arc-welding electrodes. The first two digits of the electrode classification number designate the minimum allowable tensile strength in the stress-relieved condition, (except in the E45 series where the non-stress-relieved condition is the basis) in thousands of pounds per square inch. This minimum tensile strength is, of course, to be found in the deposit from the largest diameter electrodes of that group after stress-relief. The smaller electrodes of this group might easily have more than the specified minimum tensile strength for the next higher series of classifications but they would still be in this group.

The number represented by the third and fourth digits designates the positions and current characteristics with which the electrode is useful. For example, reference to the E60 group of the classification in Table IV will establish the following facts:

(*1*) Classification E6010 designates an all-position electrode, (in diameters up to $\frac{3}{16}$ in., inclusive, only) useful with d.c., reversed polarity only. This same statement refers to all other *10* classifications as for instance, E70*10*, E80*10*, etc.

(*2*) Classification E6011 is the a.c. counterpart of the E6010 electrode. This again is an all-position electrode (in diameters up to $\frac{3}{16}$ in., inclusive, only) having the normal voltage arc and the deep penetration of the E6010 group.

(*3*) Classification E6012 is again an all-position electrode, (in diameters up to $\frac{3}{16}$ in., inclusive, only) useful with a.c. and d.c., either polarity. This and the following classification of electrode, E6013, is characterized by a low-voltage arc with its consequent lack of penetration. These two classifications of electrode E6012 and E6013, are the easiest to use in all positions, particularly because of their ability to bridge gaps.

(*4*) The E6020 and E6030 classifications are very similar, the latter producing deposits of the maximum fluidity and therefore useful only in flat position welding. E6020 electrodes give slightly less fluid deposits and therefore can also be used in the making of horizontal fillets (in diameters up to $\frac{1}{4}$ in., inclusive, only). Obviously, any E6020 electrode will fulfill the requirements of the E6030 class but the reverse is not true.

Knowing the significance of the various digits used in the classification, it is a relatively simple matter to use and understand this method. It is followed consistently throughout each series of classifications so that if an E8010 electrode is under discussion, it is immediately known that:

(*1*) The minimum tensile strength requirements in the stress-relieved condition is 80,000 psi.

(*2*) It is an all-position electrode, that is, it may be used in the flat, horizontal, vertical, and overhead positions (in sizes up to $\frac{3}{16}$ in., inclusive).

(*3*) It operates satisfactorily only with d.c., reversed polarity.

The descriptions given in Parts II to VII of the Appendix cover electrodes of the E60 series of classifications only, but in general parallel descriptions will apply to corresponding classifications in the other strength ranges. The tables of mechanical properties have been included to illustrate the differences that might be expected since the specifications show only minimum requirements.

In this manner order has been brought out of confusion, for all of the electrodes, regardless of trade names, which meet all of the requirements of any given AWS-ASTM classification may be expected to have major characteristics which

metal fluidity, are determined from experience through use of the electrode. Mechanical characteristics are determined by the all-weld-metal tension test. The ability of an electrode to yield a sound weld is determined by the

PART II

E6010—All-Position—Direct Current, Reversed Polarity Only

Class E6010 electrode is designed to produce the best possible mechanical properties consistent with good usability characteristics in all welding positions. It is characterized by a deeply penetrating, forceful, spray-type arc and readily removable, thin, friable slag which may not seem to completely cover the deposit. Fillet welds are usually relatively flat in profile and have a rather coarse unevenly spaced ripple. The covering is high in cellulose usually exceeding 30 per cent by weight, which accounts for its being referred to often as the cellulosic type. The other materials generally used in the covering include titanium dioxide, various types of magnesium or aluminum silicates, metallic deoxidizers such as ferromanganese and liquid sodium silicate. The core wire is usually a rimmed steel containing 0.10 to 0.14 per cent carbon, 0.40 to 0.60 per cent manganese, 0.04 per cent maximum sulfur and phosphorus, and 0.025 per cent maximum silicon.

This classification is always recommended for all-position work where the quality of the deposit is of greatest importance, particularly on multi-pass applications in the vertical and overhead position, where radiographic requirements must be met.

The majority of its applications are on mild steel. However, it has been used to advantage on galvanized plate and on some low-alloy steels. Typical applications include ship building, structures such as buildings and bridges, storage tanks, piping, and pressure vessel fittings. This is probably the most widely used type of electrode being produced today, the volume exceeding that of any other type. Since its applications are so wide spread a discussion of each is impractical. In some cases the $\frac{3}{4}$-in. diameter is available in two covering thicknesses either of which can be used in all positions. Improved mechanical properties are obtained with the heavier covering at some sacrifice of operating characteristics in the vertical and overhead positions. By far, the larger volume is produced with the thinner covering. Sizes larger than $\frac{3}{16}$ in. are, of course, not generally used in all positions.

Generally speaking the maximum currents that can be used with this type of electrode are somewhat limited as compared to the E6012, E6013, E6020, or E6030 types due to the high spatter loss that occurs with high currents. The following table may not apply to every brand produced but will be found satisfactory for most brands.

Electrode, Diameter, in.	Current, amp.	Voltage, arc volts
$\frac{1}{16}$	20 to 40	20 to 22
$\frac{5}{32}$	20 to 80	23 to 25
$\frac{3}{16}$	80 to 120	24 to 26
$\frac{1}{32}$	120 to 160	24 to 26
$\frac{1}{16}$	140 to 220	26 to 30
$\frac{7}{32}$	170 to 250	26 to 30
$\frac{1}{4}$	200 to 300	28 to 34
$\frac{5}{16}$	250 to 450	28 to 34
$\frac{3}{8}$	300 to 500	30 to 35

Obviously, when used in the vertical and overhead positions currents nearer the lower limit of the range should be used.

The range of mechanical properties to be expected when deposited in accordance with the test procedures prescribed in the specifications are shown in the following table:

	As Welded	Stress-Relieved
Tensile strength, psi.	62 000 to 70 000	60 000 to 67 000
Yield strength, psi.	52 000 to 58 000	47 000 to 54 000
Elongation in 2 in., per cent	22 to 28	27 to 34
Reduction of area, min., per cent	35	45
Impact resistance, ft-lb., izod	50 to 70	
Endurance limit, psi.	28 000 to 32 000	
Density, g. per cu.cm.	7.82 to 7.86	
Brinell hardness number	140 to 160	

Since this type of electrode contains no alloy ingredients other than those usually contained in the core wire, the chemical composition of the deposited metal, uncontaminated by plate material, will usually show less carbon and manganese than the core wire. The phosphorus and sulfur will not exceed 0.04 per cent each. The silicon content, however, will be higher than that of the core wire and in the case of some brands may approach 0.30 per cent.

Generally speaking, E6010 electrodes will comply with the requirements of the following codes or specifications:

(*1*) U. S. Army Specification No. 57-203, Type I, Class A.

(*2*) Army-Navy Aeronautical Specification, AN-E-9, Class B.
(*3*) American Bureau of Shipping.
(*4*) A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels, Paragraph W-520.
(*5*) A.S.M.E. Code for Unfired Pressure Vessels, Paragraphs U-68, U-69 and U-70.
(*6*) Navy Dept., Bureau of Ships, Specification 46E3(1NT), Grade 1, Classes 1, 2 and 3.
(*7*) Hartford Steam Boiler Inspection and Insurance Company.
(*8*) Lloyd's Register of Shipping, Section 4, Paragraphs 1 and 9.
(*9*) U. S. Coast Guard.
(*10*) British Corporation Register of Shipping and Aircraft.
(*11*) Building Codes of New York City, Pittsburgh, and many other Municipalities.

PART III

E6011—All-Position—Alternating Current and Direct Current, Reversed Polarity

Classification E6011 electrode is designed to duplicate the usability characteristics and mechanical properties of the E6010 classification using alternating current as the source of power. Although also usable on direct current, reversed polarity, a sacrifice in usability characteristics will be noted when compared to the E6010 electrode. When used with direct current, straight polarity, as is sometimes done, some further sacrifice in usability characteristics is noticed. Continued improvement of the E6011 type of electrode, however, may result in an electrode with usability characteristics equal to the E6010 type on direct current and thus eventually replace it entirely. Penetration, arc action, slag and fillet weld appearance are very similar to that of the E6010 electrode.

The covering is also high in cellulose. In addition to the other ingredients usually found in the E6010 electrode coverings, small quantities of calcium and potassium are usually present. The core wire used, so far as is known, is identical with that used in E6010 electrodes.

Like the E6010 electrode it performs satisfactorily on galvanized plate. It is this characteristic plus its ability to produce fillet welds similar in size and appearance to the E6010 type when the same diameters are used, that provides the necessary distinguishing features to differentiate between it and the E6013 type. Like the E6010 electrodes, sizes larger than $\frac{3}{16}$ in. are not generally used in all positions. It is, therefore, obvious that in these specifications the mechanical properties alone do not establish classification requirements.

It is therefore apparent that this type of electrode has been designed to permit the use of a.c. with its inherent advantages on all of the applications previously possible only with E6010 type electrode and d.c. Since this is a relatively new type, the volume consumed is by no means as great as that of the E6010 electrode. The current and voltage ranges usually recommended are identical to those of the E6010 electrode, and a table of recommended values is therefore not included. As in the case of E6010 electrode high currents result in high spatter loss.

The range of mechanical properties to be expected are the same as for the E6010 electrode given in Part II of the Appendix, except for tensile and yield strengths which are as follows: Usually the ductility, tensile strength, and yield strength are higher than obtained with E6010 electrodes.

	As Welded	Stress Relieved
Tensile strength, psi.	62 000 to 73 000	60 000 to 70 000
Yield strength, psi.	52 000 to 61 000	50 000 to 58 000

The chemical composition of deposited metal will fall within the same ranges as described in Part II of the Appendix on E6010 electrodes.

E6011 electrodes will comply with the requirements of the codes and specifications given in items (*3*) to (*11*), inclusive, of Part II of the Appendix for E6010, *except* that Grade 3 is substituted for Grade 1 in item (*6*).

PART IV

E6012—All-Position—Direct Current, Straight Polarity and Alternating Current

The E6012 type of electrode is characterized by medium penetration, a rather quiet type of arc, slight spatter, and dense slag completely covering the deposit. The covering is high in titania, usually exceeding 35 per cent by weight, which accounts for its usually being referred to as the titania or rutile type. In addition, the covering usually contains various silicious materials such as feldspar and clay, small amounts of cellulose, ferromanganese and sodium silicate as a binder. Also, small amounts of calcium compounds may be used to produce satisfactory arc characteristics on straight polarity. The core wire is identical with that used on E6010 and E6011 type electrodes. Whereas single pass welds may meet radiographic requirements, multipass welds fall far short.

Generally speaking, fillet welds tend to be convex in profile, having a smooth even ripple in the horizontal position and a widely spaced convex ripple in the vertical position which becomes smoother and more uniform as the size of the weld is increased. Ordinarily a larger size fillet must be made in the vertical and overhead positions than with E6010 and E6011 electrodes of the same diameter, if good fusion and profile are to be obtained.

Although E6012 electrode is an all-position type, far greater tonnages of it are used in the horizontal position than in the vertical and overhead positions. It is recommended for vertical and overhead work where more ductile weld metal is considered unnecessary although such use is generally confined to electrodes $\frac{5}{32}$ in. in diameter and smaller. It is specifically recommended for single-pass horizontal fillet welds where weld metal quality permits due to the ease of handling, good weld profile and ability to withstand high welding currents. It is probably the most satisfactory type for work involving poor fit-up. Wide gaps can be bridged quite readily.

This electrode has been used to advantage on many low-alloy steels, particularly of the higher carbon varieties. This is probably due to the fact that the penetration obtained, although adequate, is by no means the equal of that obtained with the E6010 or E6011 types. As a result, the pickup of alloying ingredients is not as great, which undoubtedly has a beneficial effect from the standpoint of cracking. Reference to the following table will show that far higher currents can be used with this type of electrode than can be used with any other of the all-position types. When used in the vertical and overhead position, current values nearer the lower end of the range should be employed.

Electrode Diameter, in.	Current, amp.	Voltage, arc volts
$\frac{1}{16}$	20 to 40	17 to 20
$\frac{5}{64}$	30 to 80	17 to 21
$\frac{3}{32}$	80 to 130	18 to 22
$\frac{7}{64}$	120 to 180	18 to 22
$\frac{1}{8}$	140 to 250	20 to 24
$\frac{9}{64}$	170 to 300	20 to 24
$\frac{5}{32}$	200 to 400	20 to 24
$\frac{3}{16}$	250 to 500	22 to 26
$\frac{7}{32}$	300 to 600	22 to 26

The weld metal deposited by this electrode is lower in ductility and higher in yield strength and tensile strength than weld metal from either E6010 or E6011 electrodes. The range of mechanical properties to be expected when welding in accordance with the test procedures prescribed in the specifications are shown in the following table:

	As Welded	Stress-Relieved
Tensile strength, psi.	62 000 to 78 000	60 000 to 75 000
Yield strength, psi.	52 000 to 65 000	50 000 to 60 000
Elongation in 2 in., per cent	17 to 22	22 to 27
Reduction of area, min., per cent	25	30
Impact resistance, ft-lb., izod	25 to 50	
Endurance limit, psi.	not determined	
Density, g. per cu. cm.	7.80 to 7.85	
Brinell hardness	150 to 170	

The chemistry of the deposited metal does not vary very greatly from that obtained from the E6010 or E6011 types. However, microscopic examination will disclose the fact that the weld metal contains far more nonmetallic inclusions.

The E6012 electrode will comply with the following codes and specifications:

(*1*) U. S. Army Specification No. 57-203, Type 1, Class B.
(*2*) Army-Navy Aeronautical Specification, AN-E-9, Class A.
(*3*) American Bureau of Shipping (with certain exceptions).
(*4*) A.S.M.E. Code for Unfired Pressure Vessels, Paragraphs U-69 and U-70.
(*5*) Lloyd's Register of Shipping, Section 4, Paragraphs 1 to 8, inclusive.
(*6*) U. S. Coast Guard (with certain exceptions).
(*7*) British Corporation Register of Shipping and Aircraft.
(*8*) Building Codes of New York City and Pittsburgh and other Municipalities.

PART V

PART VI

PART V

E6013—All-Position—Alternating Current and Direct Current, Straight Polarity

The E6013 type of electrode although very similar to the E6012, possesses some worthwhile differences. Slag removal is somewhat better and the arc can be established and maintained more readily, particularly in the case of the small diameters ($\frac{1}{16}$, $\frac{5}{64}$, and $\frac{3}{32}$ in.) thus permitting satisfactory operation with lower open circuit voltage. Originally this type of electrode was designed specifically for light sheet metal work. However, the larger diameters are being used on many applications previously welded with E6012 electrode. Even less penetration is obtained than with the E6012 electrode.

The coverings used are very similar to those of the E6012 electrode containing rutile, silicious materials, cellulose, ferromanganese and liquid silicate binders. An important difference is that easily ionized materials are incorporated in the coating which permits the establishment and maintenance of an arc with alternating current at low welding currents and low open-circuit voltages.

It is very similar to the E6012 type in operation and appearance of deposit when used in an identical manner. The arc action tends to be quieter and the deposits more polished in appearance. It is generally recommended for sheet metal applications where its ability to weld satisfactorily in the vertical position from the top down without leaving surface holes is an advantage. However, some E6012 electrodes perform similarly. Small diameters are very satisfactory for air frame construction in which case the electrode is usually used with direct current, straight polarity. Because of unsatisfactory performance on galvanized plate and decidedly less penetration, E6010 and E6011 classification for this type of electrode is impossible.

The range of mechanical properties to be expected when welding in accordance with the test procedures prescribed in the specifications is shown in the following table:

	As Welded	Stress Relieved
Tensile strength, psi.	62 000 to 72 000	60 000 to 70 000
Yield strength, psi.	52 000 to 58 000	50 000 to 56 000
Elongation in 2 in., per cent	17 to 22	22 to 27
Reduction of area, min., per cent	25	30
Impact resistance, ft-lb., izod	not determined	
Endurance limit, psi.	not determined	
Density, g. per cu.cm.	7.80 to 7.85	
Brinell hardness	140 to 160	

Ordinarily the high welding currents possible with the E6012 electrode cannot be used. When welding in the vertical and overhead positions, however, the current and voltage will be very similar. The usual recommended values of current and voltage for the various diameters that are available are given in the following table:

Electrode Diameter, in.	Current, amp.	Voltage, arc volts
1/16	20 to 40	17 to 20
5/64	40 to 80	17 to 21
3/32	70 to 120	18 to 22
7/64	120 to 170	18 to 22
1/8	140 to 240	20 to 24
9/64	170 to 300	21 to 25
5/32	200 to 350	22 to 26
11/64	250 to 450	23 to 27
3/16	300 to 500	23 to 28

The chemistry of the deposited metal is very similar to that obtained from the E6012 type. However, the weld metal is definitely less dirty from the standpoint of slag and oxide inclusions.

E6013 electrodes will comply with the same codes and specifications given in Part IV of the Appendix for E6012 electrode, *except* U. S. Army Specification No. 57-203 Type I, Class B.

PART VI

E6020—Horizontal Fillets and Flat Position—Direct Current or Alternating Current

The E6020 type of electrode is designed to produce flat or slightly concave horizontal fillets with either a.c. or d.c., straight polarity and will produce satisfactory results on fillets and groove welds in the flat position with a.c. or d.c., either or both polarities depending upon the brand. It is characterized by a spray-type arc and a heavy slag, well honeycombed on the under side, which completely covers the deposit and can be readily removed.

When normal welding currents and technique are employed penetration is considered to be medium. However, it is capable of operating satisfactorily at high currents which results in deep penetration particularly when such a technique is employed as in deep fillet welding. Of all the types of electrodes produced this is generally considered to be the best for this specialized procedure.

This is essentially a mineral-covered electrode. The slag coverage is so extensive and the slag metal reactions are of such a nature that the electrode does not normally depend on gaseous protection. The covering is such that an iron oxide, manganese oxide, silica slag is usually produced. Other constituents containing the oxides of aluminum, magnesium, or sodium are present to modify the slag. Ferromanganese is used as the main deoxidizer. The quantities of basic oxides, acid silica and silicates, and deoxidizers must be carefully controlled to produce satisfactory operation and good weld metal. Sodium silicate is used as the binder. In most cases the core wire employed is the usual 0.10 to 0.14 per cent carbon steel.

Fillet welds tend to have a flat or concave profile and a smooth even ripple. In many cases the surface of the deposit is dimpled. This characteristic is affected by atmospheric conditions,—that is to say, the more restricted the opening in which the metal is deposited the greater the tendency towards dimples. It is to be expected in practically all cases on the first few passes of deep groove welds. As the weld nears completion this tendency decreases. Many have noted the fact that the use of alternating current tends to promote this dimpled condition to a greater extent than does direct current. No undesirable mechanical or physical defects are associated with this surface condition.

Generally speaking, this electrode is recommended for horizontal fillet welds where the best of quality is desired and where rigid radiographic examination must be met. High deposition rates can be obtained with high quality on flat fillet and groove welds in heavy plate. This type of electrode is not generally used on thin sections due to increased warpage resulting from the higher currents usually employed.

Applications include pressure vessels, heavy machine bases and structural parts, where thickness of section permits.

The following table of currents and voltages which follows may not apply to every brand produced but will be found very satisfactory for most. Obviously, when making horizontal fillet welds using the conventional technique, current values nearer the lower end of the range should be employed if undercutting is to be held to a minimum. If the deep fillet welding technique is employed, the higher currents are used.

Electrode Diameter, in.	Current, amp.	Voltage, arc volts
1/16	100 to 140	24 to 28
5/64	120 to 180	26 to 30
3/32	175 to 250	30 to 36
7/64	200 to 325	30 to 36
1/8	250 to 400	30 to 36
5/32	350 to 450	32 to 38
3/16	400 to 550	34 to 40

The range of mechanical properties to be expected from the weld metal when deposited in accordance with the test procedures prescribed in the specifications are shown in the following table:

	As Welded	Stress-Relieved
Tensile strength, psi.	62 000 to 68 000	60 000 to 66 000
Yield strength, psi.	52 000 to 58 000	47 000 to 53 000
Elongation in 2 in., per cent	25 to 30	30 to 36
Reduction of area, min., per cent	40	50
Impact resistance, ft-lb. izod	50 to 70	
Endurance limit, psi.	30 000 to 34 000	
Density, g. per cu.cm.	7.82 to 7.86	
Brinell hardness	150 to 170	

E6020 electrodes will comply with the codes and specifications listed as items (*3*), (*4*), (*5*), (*7*), (*8*), (*9*), (*10*), and (*11*) in Part II of the Appendix for E6010 and in addition the following:

(*1*) U. S. Army Specification No. 57-203, Type I, Class C.

(*2*) Navy Dept., Bureau of Ships Specification 46E3(INT) Grade II, Classes 2 and 3.

PART VII

E6030—Flat Position—Direct Current or Alternating Current

Any electrode designed to fulfill the requirements of the E6020 classification will also fulfill the requirements of the E6030 classification. There are certain other electrodes with which horizontal fillet welding is impractical, if not impossible, but which do operate satisfactorily in the flat position and possess some advantages. As a result, the E6030 classification is necessary.

Since E6020 electrodes have already been described in Part VI of the Appendix, the description herein will involve only the E6030 electrode type which has been designed primarily for use in narrow groove welds.

The slag produced is usually less dense but just as easily removed as that from the E6020 type. When using direct current, best results are usually obtained with reversed polarity. Generally speaking, the E6030 type of electrode is capable of showing higher deposition rates than the E6020 type.

The coverings employed are similar to those of the E6020 type in which the slag is essentially an iron oxide, manganese oxide, silica combination with alumina, magnesium, and sodium oxide and other modifiers. In some electrodes cellulose may be present. Ferromanganese is the principal deoxidizer, although other metals and ferro-alloys are sometimes used. Again sodium silicate is used as the binder.

In most cases the core wire employed is the usual 0.10 to 0.14 per cent carbon steel.

Each layer of fillet or groove welds has a concave profile and a smooth even ripple. The tendency for the surface of the deposit to be dimpled is not as pronounced as is the case with the E6020 type.

This type of electrode is recommended for welding heavy plate in the flat position only. Applications include pressure vessels, heavy machine bases and structural parts where the thickness of the section permits. Of these, probably the greatest tonnage is used in the construction of pressure vessels where narrow deep grooves are the rule rather than the exception.

The table of currents and voltages which are found to be satisfactory for most brands that are available is identical with that shown in Part VI of the Appendix for E6020 electrode.

The range of mechanical properties to be expected from the deposited metal when deposited in accordance with the test procedures prescribed in the specifications is identical with those expected of the E6020 class. Likewise, the chemistry of the deposited metal is very similar, if not identical. This electrode, like the E6020, is especially useful where rigid radiographic examination must be met.

E6030 electrodes will comply with the codes and specifications listed as items (*3*), (*4*), (*5*), (*7*), (*8*), (*9*), (*10*), and (*11*) in Part II of the Appendix for E6010, and in addition the following:

(*1*) Navy Dept., Bureau of Ships Specification 46E3 (INT) Grade II, Class 3.

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(*Continued on page 745*)

Research—An Irresistible Force*

By Dr. Howard E. Fritz†

MR. CHAIRMAN and Members of THE AMERICAN WELDING SOCIETY: Please accept my expression of sincere appreciation for this, tonight's assignment. It is a high privilege and a personal pleasure to address you on a subject which is so full of meaning and hope for us and the generations to come. The perimeter of research is the universe. The law of research is "What are the Facts?" To violate this law leads people and nations to disaster.

Throughout the early ages man constantly struggled toward a definite goal—a goal made his objective through dire needs, his geography, and his social environment. If he was always hungry, his goal was food; if he was always cold, heat was his goal; if ill, cures became the goal. Simple, elementary necessities of life, but fear of failure to reach those goals plagued him eternally, because he could never be sure that the path ahead was the one that led to enlightenment or into despair and destitution.

The goal of early man was food. Next came religion, next freedom, and now in our day it seems to be security, so the pertinent question is, what path shall we follow for security; how shall we make our plans?

In early history, as now, the method of acquiring new knowledge was by trial. I can find no reference to the first application of the name *research* to this process of trial, but it is accurately recorded in history that near the year 1800 men began to think and plan this process of trial, and this era ushered in the chemical revolution and the beginning of modern science. It is also interesting to note that in the same era began the battle for freedom, and in rapid succession there came to civilization freedom of research, freedom and the incentive to think, thus bringing about the great developments destined to be the introduction of the "Machine Age" and the "Age of Plenty."

The Bessemer process, the open-hearth process, the telegraph, the telephone, the dynamo, the discovery of oil, the internal combustion engine, the reaper, the thrashing machine, and railroad expansion, and so we have gone on until we now stand at the threshold of a brilliant and dazzling "Chemical Era." Concurrent with this advancement, the words science and research became regular vocabulary. The difficulty is, however, that the general public does not have a full measure of understanding of the two terms and how they can benefit by the products of them.

There seems to be a wave of effort to define science and research in terms understandable to the common man. In the last analysis there really is no way to define this great source of power; it is instinctive in man. But history and progress point to certain definite conclusions which are very enlightening even though perhaps highly controversial.

Permit me to make this bold and unqualified statement, namely: that what we possess, cherish and revere in our civilization is ours as the result of accumulated science and research.

You are quick to think of exceptions and contradictions to this statement, but let me present some clinchers before you tear me apart for this impertinence.

Before proceeding to that part, permit me to briefly explain science and research.

The shortest and best definition of science that I can find is, "it is classified knowledge." Now, I know you are not much interested and don't care about such things, so accept my word that classified knowledge does the trick and plays an extremely important role in our society.

Research—well, that means anybody working any place to do something different and/or cheaper. Hence, a researcher may be anybody and a research laboratory can be a woodshed, basement, kitchen, park bench, jail, penitentiary, pigpen, chicken coop, or a modern college or industrial laboratory.

Now that I have cleared that part with you, I feel safe in stating the clinchers to which I previously referred.

1. You would be stating the whole truth if you declared that there is no phase of modern industry untouched by science. Recall that the touch of an electric light button, the surge of power in your auto, that refreshing iced beverage in summer, that invisible voice over the air, the killers of those deadly disease germs smallpox, diphtheria, rabies, and typhoid, and the countless thousands of today's necessities, comforts and luxuries without exception sprang or stemmed from a research laboratory.

2. Food and the search for it for thousands of years has been man's most desperate problem. It is a matter of historic record that hunger and undernourishment were the lot of mankind throughout the ancient and medieval times and that this was the prime reason for the plagues and pestilences which once scourged the world. But when science and research put agricultural implements and the steam and gasoline engines into our hands, the era of plenty had arrived.

3. The black and bubonic plagues of the 14th century were graver catastrophes to civilization than all of the accumulated wars combined, but a diligent, humble and skillful scientist by the name of Pasteur put an end to these ravages of mankind, through his brilliant work which led to the discovery of microbes, then vaccines and antitoxins.

4. Welding, your own and chosen profession, which has contributed greatly to a more luxurious living, and a more vicious method of warfare, passed through the research laboratory as early as 1885. I am speaking of our modern fusion welding and not of the very ancient art of hammer welding practiced by the early blacksmiths. That first art was the electric welding, next resistance welding in 1887, but even then they were in the experimental stages. In 1906 the various welding processes reached commercial maturity. With the advent of atomic hydrogen welding, and X-ray inspection, welding

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† Director of Research, The B. F. Goodrich Co.

has become of age and is now commonly accepted as one of our most priceless research treasures.

One could go on endlessly citing the accomplishments of science and research but let us have a look at the other side of civilization, just to make more convincing the statement that "our civilization is accumulated science and research," and I mean the bad as well as the good of that civilization.

1. Science taught us to wear hats, hence baldness, sinus, catarrh and colds.

2. Science displaced the carriage and wagons, and gave us the automobile and aeroplane, hence the highway and air fatalities, ill tempers and the horrors of our modern wars.

3. Science gave us chemicals, plastics and explosives, hence gas warfare, artillery, occupational diseases and thousands of other hazards and dangers because of these scientific developments.

4. Science gave us synthetic dyes and medicines, hence throwing out of their means of livelihood millions of peasants who till the soil to produce the products of nature, forcing them to other modes and practices, sometimes for better, sometimes for worse.

Truly there is no phase of our civilization which is untouched by science and research.

Let me further suggest that the spectacular advances made in the art of war are not due to *new* research but to the accumulation of knowledge in the science over many generations, and hastened to maturity by the impact of war.

Here is a typical example of the validity of that statement as quoted by Dr. C. F. Kettering, vice-president of General Motors, in a recent radio address: "Seven hundred years ago prior to 1250 A.D., an English monk carefully wrote in his diary the following: 'I have produced an explosion that outroared thunder and with a flash that exceeded the brilliance of lightning. Take seven parts of saltpeter, five of charcoal and five of sulfur.' That monk was Roger Bacon and he was describing gunpowder, but little did Bacon dream of the influence this discovery was to have on the course of civilization."

Many other things discovered hundreds of years ago are still steering the course of all mankind. There are some extremely important implications in our possessions of the present generations—passed on to us by those diligent, tireless and sincere workers of the past; their searching and restless minds through the years kept pushing back a little farther each century the veil of ignorance and superstition—that ignorance which had shrouded humanity for countless centuries and gave us the tools and the fundamental knowledge which comprises our precious heritage today.

In spite of the fact that our generation may never be able to utilize all the scientific triumphs which have been compressed into the last three years, the search must go on unabated, the reservoirs of fundamental knowledge must be constantly enriched and expanded. Remember, many of us knew for sure that there would be no World War II in our day, but we can thank a kind providence who stayed the hand of our "economic skeptics" who, through ridicule, might have prevented the full search for fundamental new knowledge and instruments for defense of our freedom. Research is a weapon for fighting the hazards of obsolescence. It is the task of specializing in change.

Let us fold back the pages of history to 1914. Here is what we see:

1. No rugged he-man ever wore a wrist watch.

2. The automobile self-starter had just come over the horizon.

3. A woman who used cosmetics such as rouge was—well, not a sissy.

4. A rubber tire did a marvelous 3000 miles of service.

5. Aluminum was almost a precious metal.

6. Rustless steel?—well, whoever heard of such a thing?

7. Tuberculosis and pneumonia nearly always fatal.

8. The diseases Spanish influenza and polio had not yet enmeshed us.

9. Insulin for diabetes was unborn.

10. Radio was an amateur's toy.

11. The word "streamlined" and the things for which it stood had not been conceived.

12. Vitamins, sulfa drugs, hormones, quinine substitutes, penicillin—if anyone would have been bold enough to suggest such things he would have become an inmate of a sanitarium.

13. Welding of any kind, except by the blacksmith, was in its infancy.

14. The Japanese owned a silk monopoly. Secure from any encroachment, Nylon was still beyond the mystic screen.

Science-wise, the nation in 1914 was in a state of coma. The chemist and scientist to the common man were the "Men from Mars," the public was loathe to experiment; suspicious of new things, the prevailing sentiment was that "My father got along with what he had for 50 years and that is good enough for me—I'll stick to my horse." Some of you present here tonight remember the early stalled automobile and the crowds that gathered to hurl verbal brick bats at the unhappy owner in his cap, gloves, goggles and duster. "Get a horse; get out and get under," we seem to hear as a hollow echo of those grim, complacent days.

World War I literally tore us out of our lethargy, whipped us into action, and initiated an era of scientific accomplishment, which can truly be recorded as the dawn of "America's Day of Eminence" among nations. A feverish search for talent began. What kind of talent? Talent that could make weapons, food, clothing and instruments to equip a military force, to compete with a savage enemy, an enemy trained and skilled for a generation in the use of scientific instruments of destruction. It soon was discovered that dispersed thinly throughout our American civilization was a fellow known as a scientist, chemist, physicist, biologist and the like, heretofore little known but tolerated as a part of the great American melting pot. It soon thereafter developed that these scientists were just what the doctor ordered, for they could design, make and constantly improve the gear necessary to wage vigorous warfare. People were bitten by the "science virus." Such names as "mystery man," creative thinker, fundamentalist, pioneers were quickly attached to these people—the day of awakening had arrived.

That war, World War I, brought home to us with terrific impact, the amazing and ruthless possibilities of a scientifically waged war. Our leaders hastily gathered the nation's pitifully small band of scientists about them and with the help of our allies we muddled through to an unsatisfactory conclusion, and in about five years we had forgotten the lessons inscribed for us in blood on the battlefields of Europe. But the scientist did not forget. He had learned that the scientific tools of war are but modifications of industry's most prized developments. He further knew that the next war would be waged from the stockpile of accumulated fundamental knowledge which stockpile he immediately set out to enrich and expand. Let us briefly scan a few of the accomplishments of science between World Wars I and II.

1. There are now known about 2000 plastics of which

perhaps 95% have been brought to the surface between the two wars, and now a new one appears at the dizzy rate of about one a month. Keep your eye on the silicones and organo-silicon halides, resisting heat up to 500° F., good electrical insulators, lubricants of great value at temperatures as low as −50° F. All made from sand.

2. DDT (dichlorodiphenyl trichloroethane), a germ-killing chemical so toxic to insects that one treatment of a space is effective for 60 days. Don't become too optimistic about a bugless world, however—that would be our finish.

3. In your own industry, atomic hydrogen welding unfolded to the world by Dr. Irving Langmuir in 1926. This brilliant research has made possible stratosphere flying and many other new and novel creations for peace and war.

4. The discovery of a medium in which to grow quantities of pure virus. This type of microbe is responsible for such diseases as typhus, the mass killer; influenza, yellow fever, infantile paralysis, the common cold, etc. Living virus cannot be seen by the use of any known instrument, thus making the job of investigation tremendous. Viruses, furthermore, only thrive on living media. To Dr. Ernest W. Goodpasture should go the thanks and gratitude of a suffering world. He found the way. His medium, a live fertile egg—a chick embryo. Grow the uncontaminated virus in the eggs, partially destroy or weaken its virulence in the form of vaccines or antitoxins and we have cheap protection against many of the virus diseases.

5. Contact lenses. They have arrived. You can now play football, go swimming, have a boxing match, wash your face, and read the paper while getting your hair cut, without taking off your glasses. Rain, sleet, wind, spray, dust, flying fragments with open vision. Invisible, comfortable, convenient.

6. Electronics, television, frequency modulation, walkie-talkies, radar, the electron microscope, the mass spectrograph have revolutionized our thinking and our doing, we are only beginning in electronics, efficient production of radio waves many times the frequency of the shortest waves known before opening up a great number of channels for our radio comfort and convenience.

7. Blood plasma, a new raw material for medicine and surgery. We will probably find it necessary to maintain a permanent bank of human blood. We will have shock cases from auto, airplane, railroad and other accidents. However, we are beginning to hear rumbling of a startling substitute discovery for human blood plasma. The product is made from gelatin, bearing the name oxpolygelatin.

8. Glass fibers and threads with tensile strengths of 3,500,000 lb. per square inch—ten times that of mild steel.

9. Rattlesnake venom for treatment of asthma, epilepsy, excessive bleeding and arthritis. The venom is dehydrated into yellowish crystals mixed with distilled water and sent off to Army and civilian medical centers all over the world. The state of Texas now has a thriving industry, based on dairy herds of rattlesnakes milked every two weeks for their lethal potion.

10. Triptane which is trimethyl butane. 150 octane motor fuel, a designed molecule.

11. Synthetic quinine, not a substitute, the real McCoy. A scientific triumph.

12. New rubbers by the hundreds—not as we have known them before—performing unique and unexpected jobs and made from wheat, corn, garbage, soyabeans, coal, petroleum, milk, sweet potatoes and salt.

In December 1910, the *Saturday Evening Post* published an article entitled, "Some Facts About Rubber," as follows:

"*It is the semiscientific inventor of synthetic rubber that is really dangerous*—to the pocket, not to the industry. One of the last men who claimed to have accomplished the making of rubber synthetically hurriedly left for England—with his backer's money—and is said to be doing time over there because of his experiments in the manufacture of synthetic shillings. He was not self-fooled. He got and gets the capitalist because *there is a remote possibility that some day rubber may be made by synthesis. I don't believe it, you don't believe it and the capitalist doesn't believe it;* but on the off chance that it may be true we gamble a few thousands and lose."

With the 1910 background, permit me to tell you about some of my own company's contributions to this amazing development of man-made rubber.

Independence from natural rubber is now an accomplished fact. Approximately one million tons of synthetic rubber of all types will be manufactured this year in the United States, most of which will be GR-S, meaning government rubber-styrene type. A fabrication of a giant synthetic rubber industry with all its ramifications, beginning from scratch and in the amazingly short period of less than four years is chemistry's greatest war achievement.

Until now, Nature was the chemical engineer in the production of crude rubber. Today, chemical engineering is essential and vital in the manufacture of the materials and in the production of man-made rubber, and this victory over Nature, even though still incomplete, has averted disaster for the Allied Nations.

Beyond the vital rubber victory looms the great importance of synthetic rubber manufacturing facilities in the world economy which will follow final victory.

For the first time in history, America is now a principal rubber producer, and the advantage of a sound basis for dealing with natural and synthetic rubber production and prices may be appreciated by examining some simple but mighty important figures.

The difference between 10 cents a pound and 20 cents a pound for rubber, based on consumption of 850,000 tons a year, would be $190,000,000, and such savings in four years would exceed the $700,000,000 expenditure for the war-necessitated government synthetic industry.

GR-S is not Buna S. So far as I can learn no one in this country ever learned or yet knows what the German Buna really is or how it is made.

To prepare GR-S, butadiene which has been liquefied by compression and cooled, is mixed with styrene, soapy water and several minor "salt-and-pepper" ingredients. The mixture is then heated and stirred under pressure, whereupon the molecules of butadiene and styrene join together to form an emulsion of synthetic rubber which is quite similar to the latex obtained from rubber-producing trees. This latex is first stabilized by treating with rubber antioxidant and heat. From here on the process of obtaining a sheeted rubber is like that used for natural rubber. The latex is coagulated with acid producing a curd.

Koroseal is a plasticized vinyl resin made from the low-cost, domestic, abundant raw materials—coke, limestone and salt. In a search for adhesives to bond rubber to metal, Koroseal was discovered as a by-product of that research. It is rubber-like, but is noninflammable, does not swell in oil and greases, and has superb aging qualities.

Immediately the war ends the material will be available in great quantities for civilian rainwear, garden hose, shower curtains, stainproof tablecloths, insulation and a host of other useful and unusual products. Koroseal, being practically a water-clear product, lends itself

to dyeing and tinting for articles of novelty and beauty. Its outstanding value to the nation has been its ability to displace or replace rubber in the emergency and in many cases at greater values to us than we ever obtained from rubber.

So then let us not perjure ourselves by knowing for sure that all these fundamental accomplishments grew out of new research for war, for it is only the rapid maturing of much earlier research.

There is an underlying reason, however, for the rapid maturing and greatly expanded research output of the nation explained by the following figures.

Industrial research activity in these United States between 1920 and 1940 increased by approximately 700%. In 1920 there existed approximately 300 industrial research laboratories. In 1940 there were more than 2200 such laboratories employing 70,000 people and spending approximately $300,000,000 annually. What is all this for? Just a search for new knowledge, from which new knowledge we hope for still further advances in our social life and comforts. But research possessing such powerfully destructive potentialities must be carefully and patiently exploited to avoid grave tragedies and blunders. Those institutions and people surging through the maze of Nature's treasures brought our scientific war effort to parity at least, with that of our enemy. They have slugged it out toe to toe with the "superman" and in the final round of the battle of the scientific giants the Germany we have known with its proficient mass standards of killing has been crushed to earth and we hope never to rise again. "Est ist verboten," the Teutonic symbol of dominance, is only a mocking memory. Here again we have that impressive lesson of the brawn of man pitted against the products of his own brain, the power of the brain always wins.

This war, any war, quite contrary to common belief, does not add to the stockpile of fundamental knowledge, rather it depletes that stockpile, because after the battle there are no more secret weapons. The military opponents have "shot the works" in the desperate struggle for victory.

Therefore, the best insurance policy of freedom for any freedom-loving nation is an overflowing reservoir of fundamental new knowledge. How shall we fill that reservoir? By drifting back into complacency as we did 25 years ago? By continuing to exploit our fellow men? By insisting on a life of ease and comfort? If you think so, then we shall mourn a war fought in vain. But if we can learn again from this bloody and senseless struggle the fundamental fact that Nature's treasure chest is the only safe frontier left for us to exploit, and we will exploit it in harmony, the basis for a civilization of luxury and freedom is established. What is the method of exploiting these treasures of Nature? A process we call scientific research. Not to be confused with research, a simple definition could well be: An attempt to know more, about more, so that we can have more, more of the time. An old adage is in order here: "The empty wagon rattles more than a full one, but carries no pay load." An empty brain also carries no pay load.

It has been said that in a dictator nation the dictator succeeds only if he can keep his subjects' stomachs full and their heads empty. That is why in such nations only a chosen few are permitted to think, but in our society, millions of free-thinking men must think and work even to the point of drudgery to preserve this most desirable and most fragile form of government. By such effort can we keep that stockpile flourishing. Our slogan for the future could well be: "Intelligent failure is commendable; inexcusable ignorance is damnable."

There seems to be a general feeling among the lay public that science is a mystery, that the people in science perform miracles. Of course that can't be true. A scientist adheres to what the facts justify and sometimes they are very simple facts and if we have failed to come far along certain roads overhung with controversy, it may be that the facts have not been developed.

This misunderstanding is a tragic misfortune. It prevents us from making free use of the products of science. Science and its accomplishments are dramatic. Some of the deepest and most cruel dramas of life have centered around the lives of scientific people. Lavoisier, the discoverer of combustion (The principle of all our prime movers today) put water in the soldiers' tobacco to keep it moist and was ruthlessly sacrificed in the inferno of political corruption.

Madame Curie, twice winner of the Nobel Prize, rejected wealth, was indifferent to honors, and finally died a victim of her own scientific triumps, radioactive bodies.

Pasteur, the patient little man of microbe fame. (At that time microbes were a subject of ceaseless jesting.) His life was threatened if failure was his lot in a chosen public experiment, but from this early beginning modern surgery had its start. His was a great lesson in humility.

The Wright brothers, after many rebuffs in their own country, were recognized by the European nations, and the original flying machine was exiled to the Science Museum in London.

Thomas A. Edison, then a telegraph operator, was fired from his job for his first invention—a telegraph repeater.

Charles Goodyear made some of his experiments on the vulcanization of rubber while confined in a Philadelphia jail as a common debtor.

At one time while trying to make his electric motor, Thomas Davenport tore his wife's silk wedding dress into strips for insulating the coils of wire.

History is replete with these scientific dramas to the everlasting humility and discredit of mankind. The military graveyards of the world are filled with expendables in payment for the arrogance and selfishness of ignorant aggressors. But the civilian graveyards are filled with many more martyrs of a misunderstanding public who refused to experiment and thus ignored the fruits of science and permitted them to rot in the field unharvested.

Scan your own experience on the most recent past and I dare say that you had a close kin, dear friend or business associate sticken with a malady such as diabetes, pernicious anemia, diphtheria, tuberculosis, yellow fever, influenza or smallpox, who walks beside you today only because of that priceless preventive or cure, but that is not all, cancer, infantile paralysis, heart disease, leukemia, and many others are still behind the veil of ignorance. When the polio epidemic strikes this fall you will gather your loved ones about you and pray to a soverign God that you and yours may be spared the ravages of that awful disease. But that is not enough. Oratory promises and wishing will never solve anything. We must probe, plan and devise the modern weapons with which to fight. Research and trial is the answer. It has been the answer thousands of times before, it will not fail us now. If we are to sustain our standard of civilization we must give all possible impetus and encouragement to those people who will be constantly plowing the new ground in search for that more bountiful harvest through the "frontiers of thinking." Such action will fill to flood tide the reservoir of fundamental new knowledge. Yours and my major obligation to society is to promote scientific tolerance and a greater depth of understanding and comprehension for those new revelations which the human mind will uncover in this boundless universe.

Remember, there is no such thing as mass production

of creative thinking. We can dominate, threaten and drive, but such methods will not and cannot inspire, and inspiration is and can only be the product of free men.

In spite of the fact that most of the world is living in an era of terror in which men seem to be willing to surrender those rights for which their predecessors were willing to fight and die, we in this nation still cling to an immortal document of independence and a concept of human liberties. The traditions of America have been cruelly wounded but have refused to die because they are rooted in the golden principle of equal opportunity and justice for all.

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THE AMERICAN WELDING SOCIETY

ACTIVITIES – RELATED EVENTS

NEW GUIDE AND SPECIFICATIONS FOR IRON AND STEEL ARC-WELDING ELECTRODES

The continual increase in the applications of metal arc welding may in part be ascribed to the concurrent advance in the development of new and improved types of electrodes, each designed to do specific jobs in the most efficient manner. To provide for classification of the various types, the AMERICAN WELDING SOCIETY and American Society for Testing Materials have jointly undertaken the formulation of specifications for these materials.

The largest volume of electrodes produced is for the welding of mild and low-alloy steels. Electrodes of this type, identified by the well-known classification numbers E 6010, E 6011, etc., are covered in Tentative Specifications for Iron and Steel Arc-Welding Electrodes. This standard has been in use for several years and has been revised periodically. The most recent revision has just been completed. The new issue, carrying the Designation A 233-45T embodies revisions which, while making some modification of previous test requirements, are primarily intended to clarify these tests requirements by more specific definition of what is required for each classification, and how the required tests are to be performed. For more ready reference, test conditions and results have been included in tabular form, and a new table has been added summarizing all test requirements.

New Guide

In the course of preparing this revision it was recognized that there are much data on electrodes which, while not proper for inclusion in the specifications, would be useful to potential users in guiding them toward an understanding of the best suited applications for the various electrode classifications established by the Specifications. To provide this information the "Guide to A.W.S.-A.S.T.M. Classification of Iron and Steel Arc-Welding Electrodes" has been prepared to supplement the specifications and has been included as an appendix to them.

This "Guide" explains the concept of the classification numbering system used in the specifications and a discussion of each electrode classification in the E 60 series as to type of coating, suitable currents and voltages and mechanical properties. Also included is a list of codes with which each classification complies.

Individual copies of the revised specifications A 233-4 5T, and the appended Guide, may be obtained from either the AMERICAN WELDING SOCIETY, 33 W. 39th St., New York 18, N. Y., or the American Society for Testing materials, 260 South Broad St., Philadelphia 2, Pa., at 25 cents per copy.

MEMORIAL RESOLUTIONS

(Adopted by Board of Directors, A.W.S., June 28th)

ALFRED VICTOR DE FOREST

Resolved that there be spread on the records of the AMERICAN WELDING SOCIETY and transmitted to the family of Professor A. V. de Forest and the Company with which he was affiliated, in memorian and appreciation, that:

Alfred Victor de Forest died on April 5, 1945, at his home at Marlboro, New Hampshire. He was one of the most distinguished members of the AMERICAN WELDING SOCIETY. By person and achievement he honored his Alma Mater, the Massachusetts Institute of Technology, from which he was graduated in 1911. After further study at Columbia and teaching at Princeton, he worked in applied research for the American Chain Company. Subsequently Prof. de Forest was consultant to various companies including Hamilton Standard Propellers, Spang Chalfant Company and John Chatillion and Company. In 1934 he joined the Faculty of the Massachusetts Institute of Technology where he was for some years Professor of Mechanical Engineering in charge of the dynamic testing laboratories. He was founder, President, and more recently, Chairman of the Board of the Magnaflux Corporation.

Professor de Forest was an energetic contributing member of technical committees of a number of societies. He was best known in the welding and metallurgical profession for his inventions and developments in the field of testing and more particularly magnetic testing. For this and many other achievements de Forest was acclaimed by his associates and this acclaim took the form of the Dudley Medal of the American Society for Testing Materials in 1928, the Longstreth Medal of the Franklin Institute in 1936, the Sylvanus Albert Reed Prize of the Institute of the Aeronautical Sciences in 1938 and the Howe Memorial Lecturer of the American Institute of Mining and Metallurgical Engineers in 1941.

Alfred Victor de Forest was well and kindly known. His friendly wit endeared him to his colleagues. A man of broad interest, ever willing to give counsel, a man of vision, ever looking beyond the horizon, a man of daring and courage tempered only by knowledge; a scientist and humanitarian, an inspiration to all who knew him; and a man best characterized in his favorite position at the helm of his small sailing ship, always headed out and up, to chart the unknown and to push back the horizon.

* * *

EDMUND A. DOYLE

Resolved, that there be spread on the records of the AMERICAN WELDING SOCIETY and transmitted to the family of Edmund A. Doyle and the Company with which he was affiliated, in memorian and appreciation, that:

Edmund A. Doyle died suddenly at his Home, New York City, on May 4, 1945.

Mr. Doyle had been an active member of the AMERICAN WELDING SOCIETY ever since its formation. He served on many standing and technical Committees and as a Director; and was President of the AMERICAN WELDING SOCIETY in 1930-31. He was responsible for organizing the important Committee on Building Codes, and until his election as President of the SOCIETY served as Chairman of that Committee.

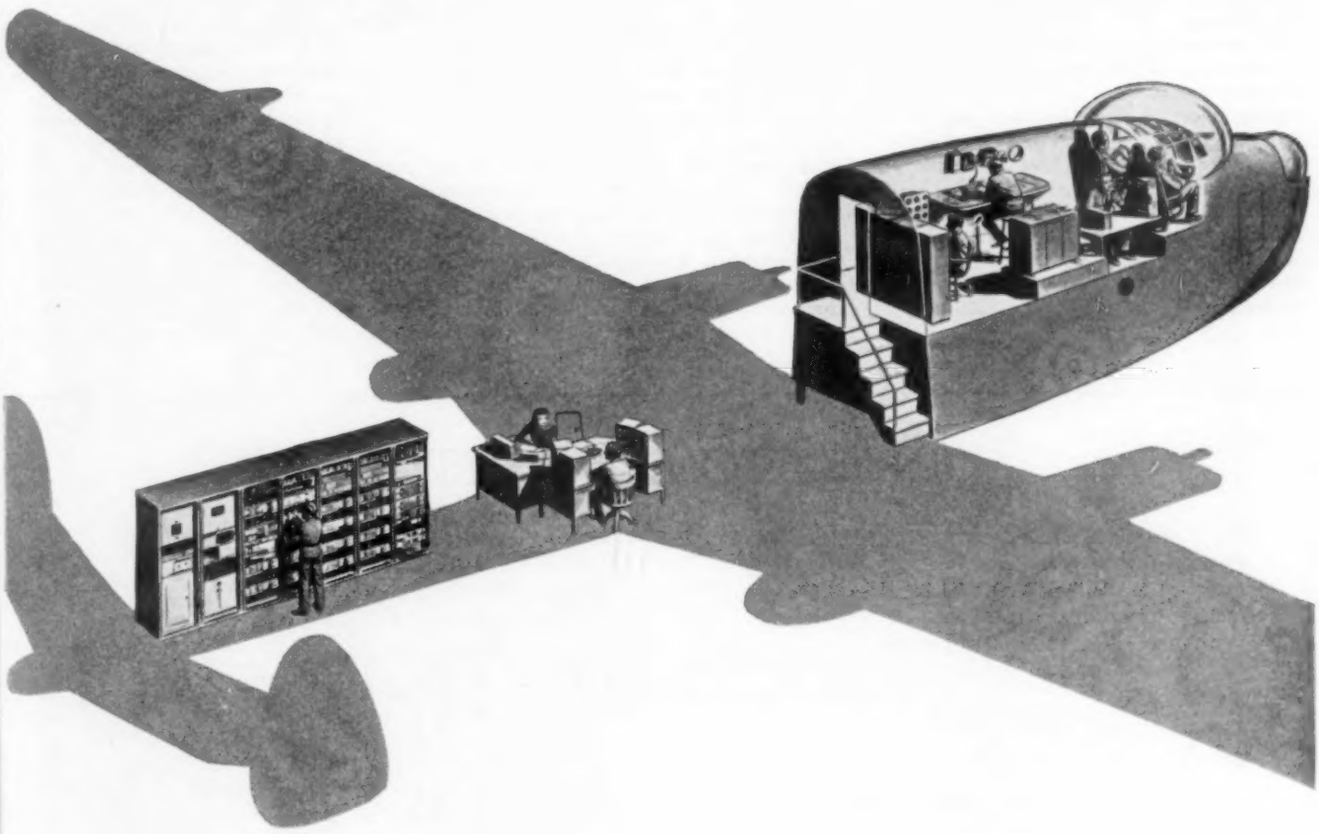
Mr. Doyle received his early education in Baltimore, Maryland, and was graduated from Johns Hopkins University in that city, as a mechanical engineer. During the first World War he served in the Corps of Engineers of the United States Army, entering the service as a first lieutenant and rising to the rank of major.

Mr. Doyle's first interest in the welding and cutting processes dates back to 1908, when he took part in the raising of the battleship *Maine* from Havana Harbor. He followed up this early interest by studying oxyacetylene welding and cutting at the trade school of the Davis-Bournonville Company. Later he entered the employ of this company as a salesman. He rose through successively more responsible assignments to the position of general manager.

Mr. Doyle became connected with The Linde Air Products Company in 1922, entering this organization as assistant general sales manager in charge of service. Four years later he became consulting engineer on process development, a position which he held until his death.

Edmund A. Doyle made many warm

THIS SEA-GULL LIVES ON THE GROUND



This is a "flight trainer"— an electronically operated replica of the PBM-3 flying boat. It was conceived by the Bureau of Aeronautics and developed by Bell Telephone Laboratories to train Navy bomber crews on the ground.

The new crew climb a few steps to get in and from then on it is like being in a big plane at night. Controls tug against the pilot's grasp and "engines" roar in response to the throttle. From his desk, the instructor creates every situation of real flight — even to iced-up wings, conked-out engines and sudden air-pockets. The novice pilot and his crew get the feel of danger without the hazard.

Once the control dials are set, the various effects are automatically organized and set in motion by concealed machinery which includes 200 vacuum tubes, 60 motors, loudspeakers and hundreds of associated parts. Twenty Laboratories engineers worked more than a year developing the project. Drawings covered an area equal to 15,000 square feet.

This is only one of the 1200 projects in which our experience has been able to help the Armed Forces. What we have learned in devising electronic circuits to train flyers will help build better telephones.

BELL TELEPHONE LABORATORIES

Exploring and inventing, devising and perfecting for the Armed Forces at war and for continued economies and improvements in telephone service.

friendships among men in the welding industry. They will remember him for his inspiring leadership, his administrative skill, his sound engineering background and his genuine good-fellowship.

CLAUDE J. HOLSLAG

WHEREAS we, the members of the Board of Directors of the AMERICAN WELDING SOCIETY, have learned with deepest sorrow of the untimely death on June 11, 1945, of C. J. Holslag, President of Electric Arc, Inc., Newark, N. J.; and

WHEREAS Mr. Holslag was a pioneer in the evolution of the welding art, as well as in the development of the AMERICAN WELDING SOCIETY; and

WHEREAS this SOCIETY feels keenly the loss which it has sustained in the death of Mr. Holslag; and

WHEREAS we, the members of the Board of Directors of the AMERICAN WELDING SOCIETY, honor Mr. Holslag for his integrity, sincerity, sound business judgment and understanding, and wish to express the esteem in which we hold his memory for his qualities, his keen mind, his patience and generosity, which made him an unfailing source of inspiration to all who came in contact with him, and in appreciation of his outstanding services to the AMERICAN WELDING SOCIETY: Therefore be it

Resolved, That we place on record an expression of our deep sympathy with Mr. Hoslag's family in the bereavement which they have suffered, and also with his business associates in the Electric Arc, Inc.; and be it

Resolved further, That the Secretary of the AMERICAN WELDING SOCIETY be instructed to spread these resolutions upon the records of the AMERICAN WELDING SOCIETY and to transmit an engraved signed copy thereof to Mr. Holslag's family and to the officers and directors of the Electric Arc, Inc.

GEORGE T. HORTON

WHEREAS in the death of George T. Horton the AMERICAN WELDING SOCIETY has suffered an irreparable loss; and

WHEREAS his wisdom and spirit of generous wholehearted service as member and Past-President have contributed largely not only to the growth and success of this SOCIETY but also to the evolution of the science and art of welding; and

WHEREAS this chaotic world is in sad need of such a spirit of wisdom and sympathetic understanding: Therefore be it

Resolved, That the Board of Directors of the AMERICAN WELDING SOCIETY hereby express their deep sympathy to Mr. Horton's family and associates, and their conviction that his spirit will carry on into the lives of many fortunate enough to have felt his influence either directly or indirectly; and be it

Resolved further, That this resolution be spread on the records of the SOCIETY and that copies thereof be transmitted to the members of his family and to his business associates.

OBITUARY

Claude J. Holslag

Claude J. Holslag, President of Electric Arc, Inc., of Newark, N. J., died on June 11th in the Presbyterian Hospital at the age of 60.

Mr. Holslag was a graduate of Columbia University. He was with the New York Central Railroad before becoming one of the founders of the Electric Arc Cutting and Welding Company in 1918 and President in 1922.

Mr. Holslag was one of the founders of the AMERICAN WELDING SOCIETY. He was a member of the Emergency Fleet Welding Committee during World War I. He pioneered in the development and use of covered electrodes and a.-c. welding. His work in this field was carried on in spite of great opposition and won him the Samuel Wylie Miller Medal of the AMERICAN WELDING SOCIETY in 1939. Mr. Hol-

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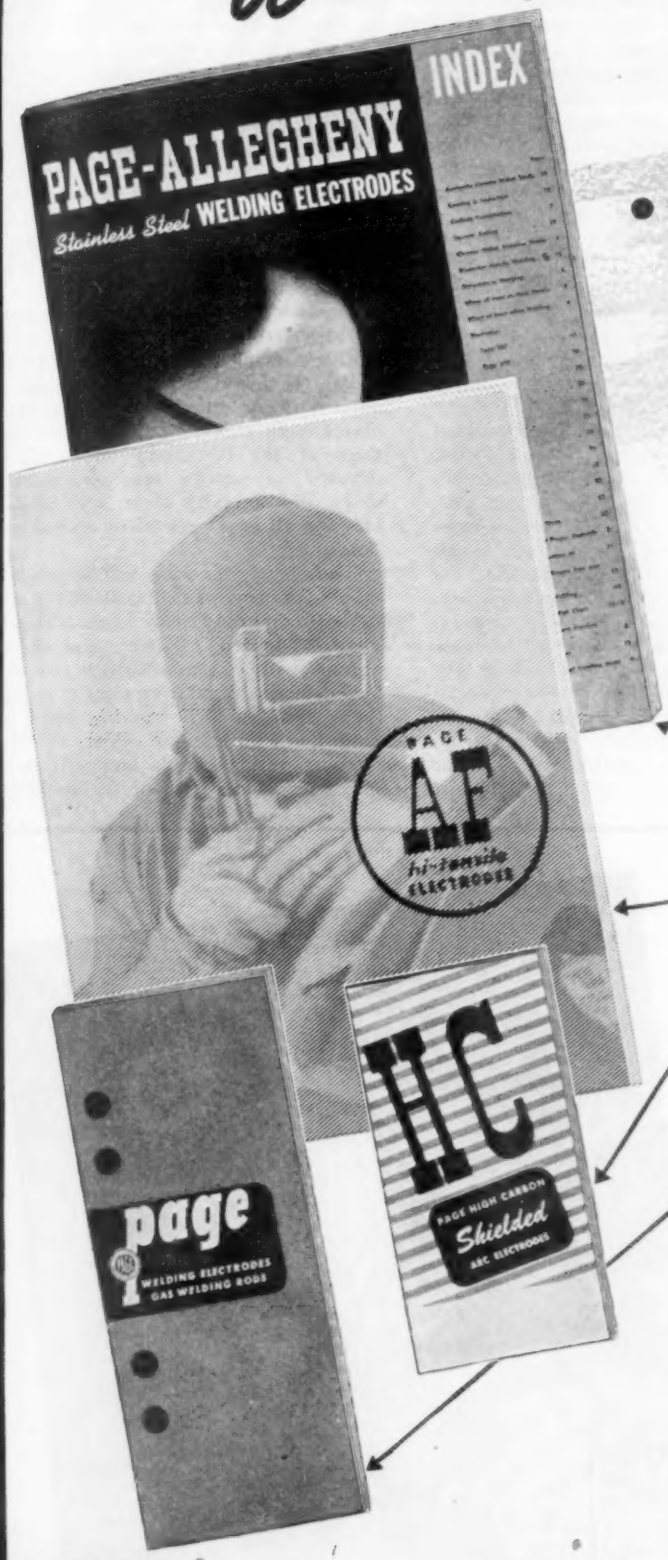

...YOURS FOR BETTER WELDING

• The three booklets and the leaflet shown here are for everyday use. Their purpose is to give welders up-to-date information on the selection of electrodes for specific jobs and how to use them to get best results.

DH-1023—If you are welding stainless steel, this 24-page booklet will be of value to you. It is almost a textbook on stainless steel electrodes and their proper use.

DH-936—This booklet is much more than a description of PAGE AF Hi-Tensile Electrodes. It is a comprehensive illustrated manual on their use.

DH-1174—This is a leaflet which describes the physical, chemical and working characteristics of the PAGE High Carbon Shielded Arc Electrode. It also lists a few of its many applications.

DH-821—Probably the most all-around useful booklet of all. It is a pocket-size catalog, arranged so that the recommended electrode or gas welding rod for any one of 28 classes of production welding can be found immediately.

★ ★ ★

Ask your nearest PAGE distributor for copies of one or more of these informative pieces. Or, if you prefer, write direct to the PAGE factory at Monessen, Pennsylvania.

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PAGE STEEL AND WIRE DIVISION
AMERICAN CHAIN & CABLE

slag lived to see the day when covered electrodes and a.-c. welding were universally accepted. Mr. Holslag was a great inventor and owned 200 patents in the welding field. He served on many committees of the SOCIETY and has written a number of important papers. He is also author of an Arc Welding Handbook now in its tenth edition.

In addition to being a member of the AMERICAN WELDING SOCIETY, he was also a member of the American Institute of Electrical Engineers, the National Electric Manufacturers Association, the New Jersey Society of Professional Engineers, the Society of Naval Architects and Marine Engineers, the New York Railroad Club and the New York Engineers' Club.

He leaves a widow, Mrs. Elizabeth Holslag; a daughter, Mrs. William L. Moore of Darien, Conn.; a son, First Lieut. Joseph with the AAF, and a brother, Russell Holslag of Brooklyn.

In the death of Mr. Holslag the welding industry and the AMERICAN WELDING SOCIETY have lost an outstanding friend whose genial good humor and fellowship endeared him to all.

GENERAL ELECTRIC'S NEW RESEARCH LABORATORY

A new building for the General Electric Co.'s Research Laboratory, which will afford some 50% more space than present facilities provide, will be erected near here at a cost of $8,000,000, it was announced on May 31st by President Charles E. Wilson. Construction will begin as soon as WPB approval can be obtained.

The site has been a private estate known as "The Knolls," and includes 219 acres. It is in suburban Niskayuna, about 4½ miles from the main plant and offices in Schenectady. Overlooking the Mohawk River, it is on a rocky cliff which will afford an excellent and solid foundation for the laboratory buildings. The river at this point forms part of the New York State Barge Canal, and the Troy branch of the New York Central runs along the bank, so there will be ample water and rail transportation available. In addition, the river will afford a good supply of water for laboratory use.

"The two buildings now occupied by the Laboratory were built in 1914 and 1922," said Dr. C. G. Suits, G-E Vice-President and Director of Research, "and while they were the last word in laboratory construction then, this is no longer true. For some time we have been cramped for space and this condition has been aggravated in the past few years when all our facilities have been devoted to war work. We have a very much expanded program for the postwar years, which will increase our staff from its present 540 to about 800.

"We must look ahead even 15 or 20 years beyond this, when still further expansion may be required. We will probably need to build smaller structures for special purposes, for example, a pilot plant for a new chemical process. All this requires not only a building that is immediately suitable, but one to which we can add and with ample grounds around it for the other buildings.

"Lack of space adjacent to the Schenectady Works, as a result of wartime construction which has utilized all prospective building sites, has forced a consideration of other locations. The one selected, in Niskayuna, and the laboratory building that we are planning will meet these needs ideally. Every new and modern feature will be incorporated and I feel confident that we will have one of the finest and most complete research institutions in the world."

The new building, in the general shape of the letter T, will vary from two to five stories in height and will include 200,000 sq. ft. of laboratory working space in addition to an auditorium seating 300, a dining room, conference rooms, etc. One-third of the laboratory space will be devoted to service facilities, machine shops and specialty shops such as glass blowers, all in a convenient central location.

Walls between rooms will be movable, capable of being placed at 18-in. intervals so that rooms may easily be made large or small as desired. Benches and all furnishings will be standardized so that they can easily be shifted from place to place as the need arises. The building will be air conditioned throughout. Wires and pipes carrying various kinds and voltages of electricity, compressed air, suction, illumi-

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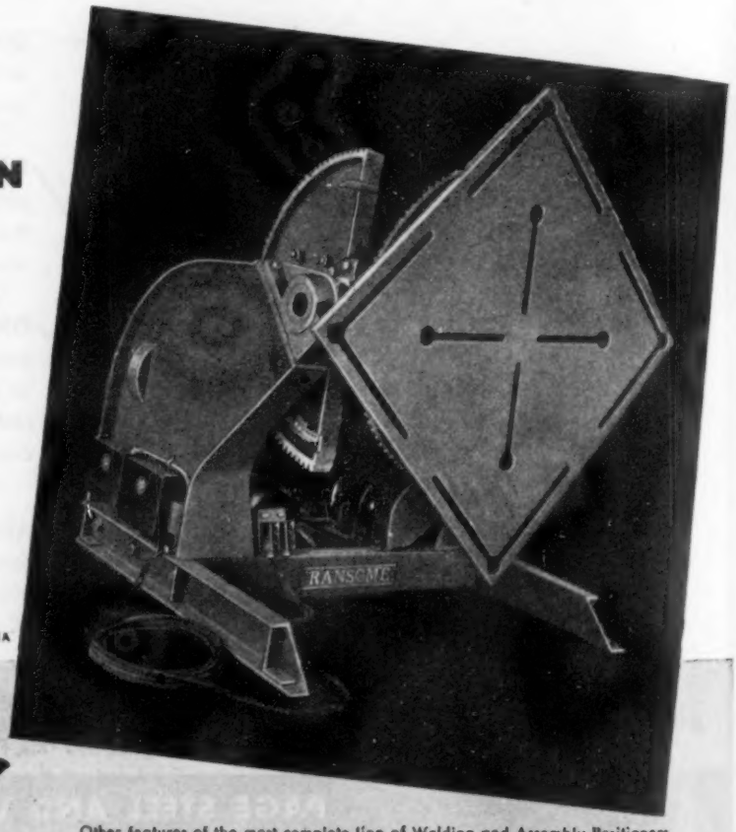

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DUNELLEN, NEW JERSEY
Subsidiary of WORTHINGTON PUMP AND MACHINERY CORPORATION

Other features of the most complete line of Welding and Assembly Positioners —100 lb. to 40,000 lb. capacity—are covered in Bulletin No. 210. Write today.

New ELECTRONIC CONTROL FOR SMALL RESISTANCE-WELDING JOBS

This new G-E electronic heat control used with a small bench welder is an important factor in the high production rate attained in the welding of electronic tube parts.

WHAT IT OFFERS YOU

1. **Synchronous Precision Timing**
   a. Easy, accurate adjustment
   b. Uniform results
2. **Electronic Heat Control**
   a. High production
   b. Little or no distortion of material
   c. Satisfactory welding of small difficult-to-weld parts

NOW you can be certain that your low-capacity spot welders will be precisely controlled, insuring better welding results. When connected to a suitable transformer, this control, used either on a bench welder or with welding tongs, makes an ideal combination for welding of all sorts of small parts. A good example of this is in the welding of tube parts where tungsten, fernico, copper, tantalum, magnesium, and molybdenum are constantly being welded with good results.

Synchronous Precision Timing

You know that accurate control of weld time is essential to the consistent welding of small parts, because the optimum weld time for high production and little distortion is less than ten cycles. In fact, it is often only one or two cycles.

Synchronous precision timing enables you to adjust the weld time in one-cycle steps from one to ten cycles. Also, with this type of timing you are assured that the preset timing will be exact (no deviations from weld to weld).

Electronic Heat Control

You also know that, in welding small parts, it is vital to have a means of adjusting the current to very close values, as relatively slight changes in welding current will result in either no welds, weak welds, or burned parts. Adjustable electronic heat control provides the necessary preciseness of current control for welding small parts—especially those metals and alloys which are difficult to weld consistently.

Flexibility of Operation

This equipment is suitable for operation on either 230- or 460-volt, 60-cycle power supply. Because the tubes have the same current rating on either voltage, the transformer that is used on a 460-volt supply can be twice as large as that required on a 230-volt source—this will approximately double the secondary or welding current.

How This Control Can Help You

If you're doing small welding jobs, this control can undoubtedly help you speed up production by providing precise welding control, and thereby reducing rejects. Our local office will be glad to send you further information on the CR7503-A140A2 timer, or talk over the possibility of installing these controls on your assembly line. However, if you prefer, write directly to General Electric Co., Schenectady 5, N. Y.

RESISTANCE-WELDING CONTROL

GENERAL ELECTRIC

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Buy all the BONDS you can—and keep all you buy

nating gas, hydrogen, oxygen, etc., will interlace the building whence they can be brought into any room.

The high elevation of the site above the river will afford many advantages, for example, in experiments with radar, high-frequency jet engines. The rocky cliff foundation will be useful in conducting experiments with X-rays. These are being produced at 100 million volts in the present laboratory, and further increases are expected.

EYE PROTECTION

To aid in furthering the eye protection of industrial workmen, a new research program has been initiated at Battelle Institute, Columbus, Ohio, under the sponsorship of the American Society of Safety Engineers, Engineering Section of the National Safety Council.

To involve a year of investigation, the program is intended to provide information that will be used by safety experts and eye-protector manufacturers to help in combating the some 75,000 disabling eye injuries and several hundred thousand nondisabling injuries that occur annually in American industry. The investigation will apply particularly to the evaluation of the performance requirements and specifications of satisfactory plastic eye protectors, which are now finding increasing use in industry.

As explained by Clyde Williams, Battelle director, eye protectors—such as goggles and face shields—are the final means of eye protection for individual workmen. When correctly designed—and when worn—they protect the worker's eyes from flying chips of metal, spattering chemicals, sparks and other hazards of industry. If not of sufficient protective power, however, they give false security; and if uncomfortable or tiring to the eyes, workmen refuse to use them and, instead, "take their chances." Taking chances in 1943, according to reports of the National Safety Council, resulted in 75,000 eye injuries to workers, 5000 of which were permanent.

During the war years there has been a rapid increase in the use of transparent plastic materials for the lenses of goggles, for the eye pieces of gas masks, and for eye and face shields. The quality of these protectors range from those in which consideration has been given to strength and optical properties to protectors untested in these respects. Recognizing that plastic eye protective devices are now in use and that their application in industry may expand, the National Safety Council wishes to establish performance requirements and specifications for satisfactory plastic eye protectors.

The research by Battelle will include both laboratory and statistical investigations. A field survey of present experience with various types of plastic eyepieces will be made to study the types of devices in use, nature of hazards, protection experience, evidence of eye strain, acceptance and use by workmen, and other evidences of advantages or disadvantages. Proceeding concurrently will be physical and optical tests to determine adequacy of protection, design, light transmission, eye strain and fatigue and other factors. The combined data will be used by eye-protector manufacturers in setting standards for their products and in industry for the specification of desirable types of protectors.

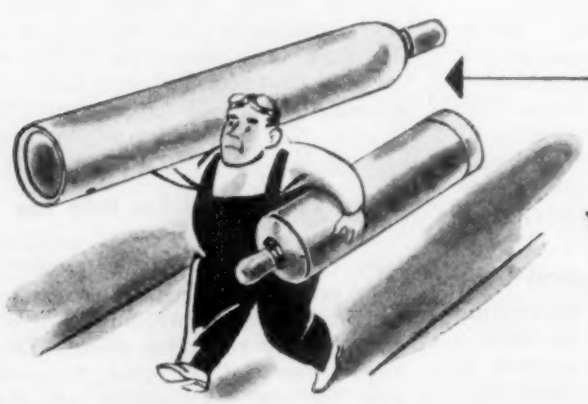
The National Safety Council is a nonprofit organization supported by industrial, trade, association and individual membership. It promotes safety in every field of human endeavor by the gathering and distribution of information about accidents and methods for their prevention.

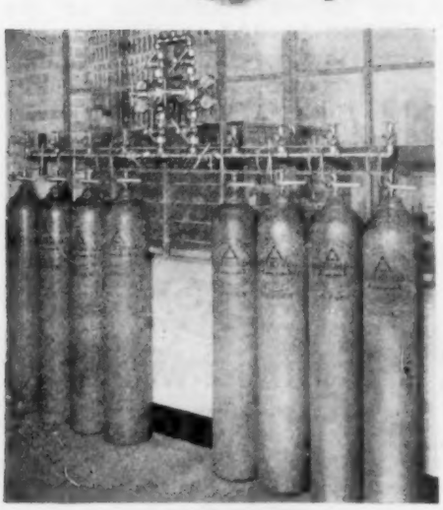
Battelle Institute, which will conduct the research, is an endowed nonprofit foundation for education and research in industrial science, including metallurgy, chemistry, ceramics, fuels, mining, engineering physics, welding, graphic arts and production research.

ANNOUNCEMENTS OF NEW A.S.T.M. OFFICERS 1944-45

Nominations for officers of the American Society for Testing Materials, for 1944-45 are announced. Official notice of election was given at the forty-eighth A.S.T.M. Annual Meeting, this year a business session in New York on June 27th.

President (Term—1 year): J. R. Townsend, Materials Engineer, Bell Tele-





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Pioneers and Leaders in Equipment for Using and Controlling High Pressure Gases

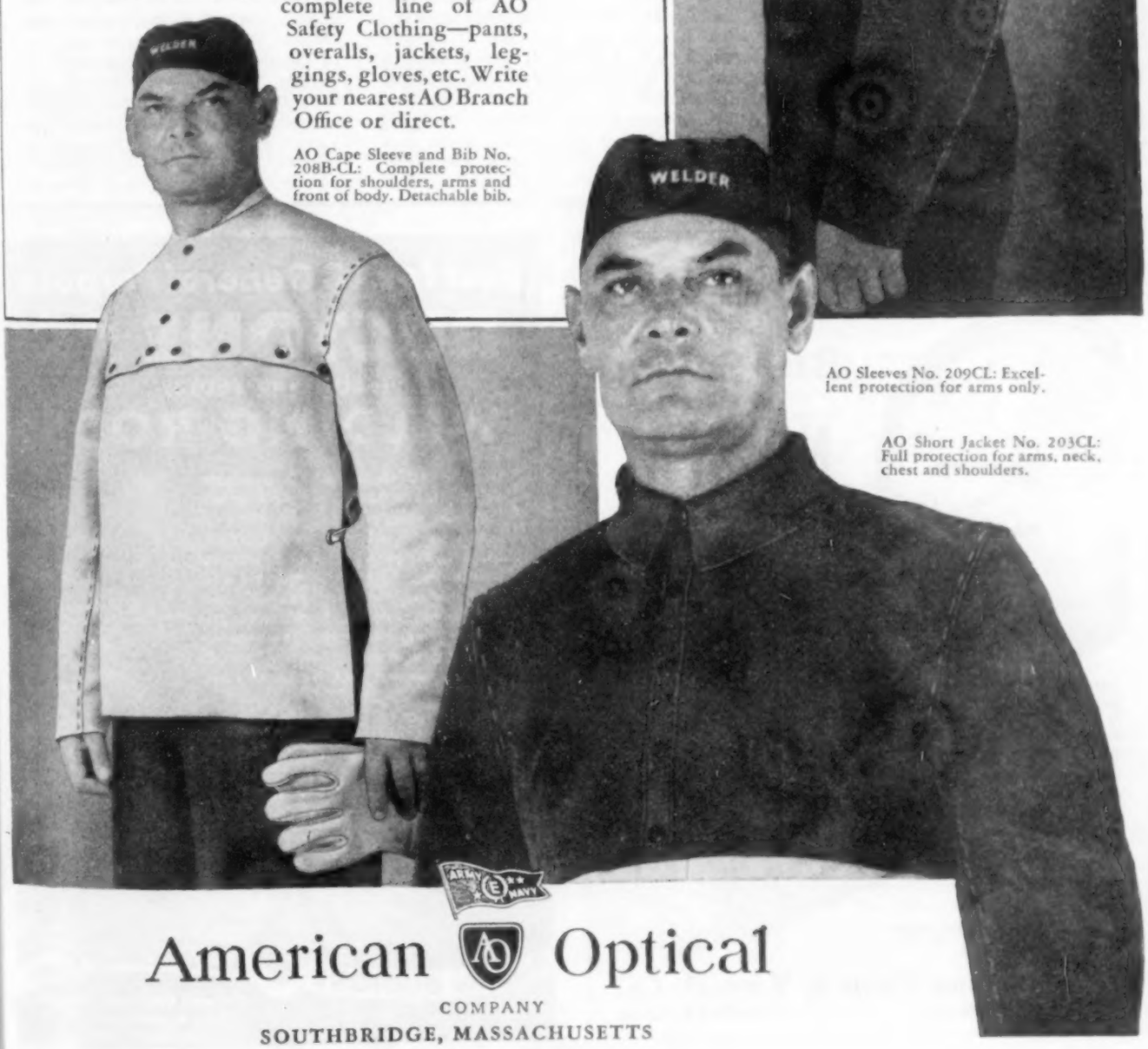
Welders Work More Comfortably—More Efficiently in

AO SAFETY CLOTHING

These welders are ideally dressed for bench welding, cutting and burning during the hot months. Cut for free action out of high-grade chrome tanned leather, each of the garments provides ample protection for the exposed parts of the body without adding uncomfortable weight for unneeded coverage. Send for catalog showing complete line of AO Safety Clothing—pants, overalls, jackets, leggings, gloves, etc. Write your nearest AO Branch Office or direct.

AO Sleeves No. 209CL: Excellent protection for arms only.

AO Short Jacket No. 203CL: Full protection for arms, neck, chest and shoulders.



AO Cape Sleeve and Bib No. 208B-CL: Complete protection for shoulders, arms and front of body. Detachable bib.

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BUYERS' GUIDE METAL INDUSTRIES

Free distribution is now being made of the 1945 Edition of the Buyers' Guide of the Metal Industries. Published by the American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio, this 108-page product directory features an extensive engineering data section.

Charts and tables in this 43-page data section present a broad range of helpful information, including trade names of tool steel and corrosion and heat-resisting alloys; the compositions and properties of magnesium alloys; nomenclature of copper alloys; fluxes for welding and brazing; machinability rating of various metals, with recommended cutting fluids for normal machining operations; metal powders—grades and data, and other information required in metals specifications and use.

Some 600 products and their manufacturers are shown in another section with a final division in the book devoted to an alphabetical listing of these manufacturers with their complete address.

Copies of the Guide will be mailed free upon request of the American Society for Metals.

SELECTING PROPER FILLER METAL

A new digest of pertinent facts about the complete line of Page electrodes and gas welding wires, written "from the buyers' stand-point" is just off the press. Each of its 33 pages contains information which will help make it easier for buyers to select the proper electrode or gas welding rod for their particular work.

Starting with the index, the booklet is designed to be of the greatest possible help in the selection of the correct welding filler metal. This index is unusual because it is based on the type and class of material which is to be welded, thus making it easier to select the electrode or gas welding rod which is best suited for welding a particular type of steel. Through the book, each page gives digested but useful data arranged for ease of reading and using. On these pages are such important facts as physical properties, analyses of the weld metal deposit, operating characteristics, recommended current ranges and other necessary information.

Copies of this DH-821 Digest can be obtained by writing to Page Steel & Wire Division, American Chain & Cable Co., Inc., Monessen, Pa.

WILSON DISTRIBUTOR

Mr. T. B. Hasler, President of Wilson Welder and Metals Co., Inc., announces that effective July 1st the Graybar Electric Co. has been appointed exclusive distributor of the Wilson brand of electrodes in the area served by Graybar's Cincinnati, Pittsburgh and Cleveland offices.

Wilson electrodes include a complete line for a.-c. and d.-c. welding of ferrous and nonferrous metals and alloys.

LINDE PLANT

The Linde Air Products Co., a Unit of Union Carbide and Carbon Corp., has announced the award of a contract to Robert E. McKee, Inc., of El Paso, Tex., for the construction of a distributing plant in Odessa, Tex., to supply this area with one of the Company's main products, Linde oxygen. Construction will begin immediately and it is expected that the plant will be completed by August 15th. Railroad service will be provided by a spur track from the Texas and Pacific Railway.

TIME
IS THE
BIG Saving
WITH
NO-SPAT
THE NON TOXIC
WELDING FLUID
Saves cleaning time by keeping adjoining surfaces free of spatter. Maintains Welding Strength — ⅓ less fumes — No Monoxide — Inexpensive—Ready to use — Saves Labor — Saves Money.
ENGINEERING INFORMATION
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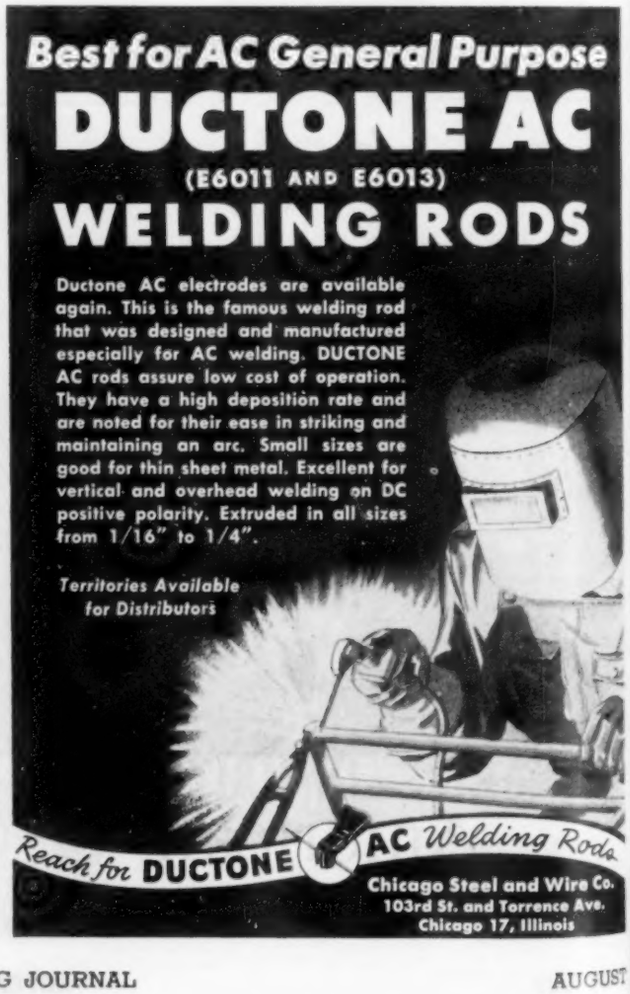

Best for AC General Purpose
DUCTONE AC
(E6011 AND E6013)
WELDING RODS
Ductone AC electrodes are available again. This is the famous welding rod that was designed and manufactured especially for AC welding. DUCTONE AC rods assure low cost of operation. They have a high deposition rate and are noted for their ease in striking and maintaining an arc. Small sizes are good for thin sheet metal. Excellent for vertical and overhead welding on DC positive polarity. Extruded in all sizes from 1/16" to 1/4".
Territories Available for Distributors
Reach for DUCTONE AC Welding Rods
Chicago Steel and Wire Co.
103rd St. and Torrence Ave.
Chicago 17, Illinois

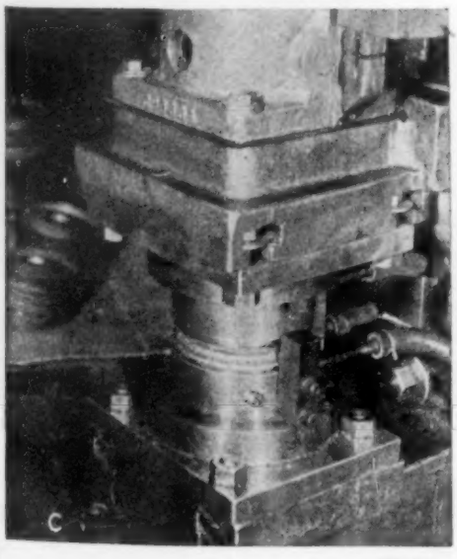
WELDING 100%

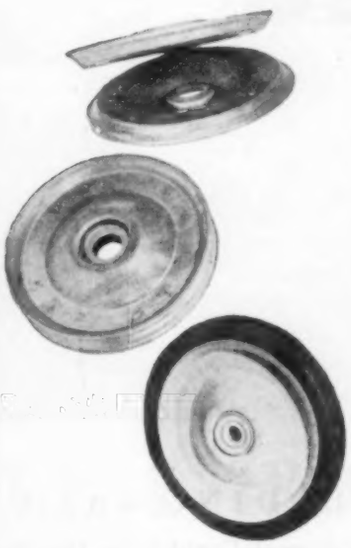
from alloy castings, installed on the standard Federal press welder, and the problem was solved. The new method, producing 1,000 wheel blanks per hour, is shown below in pictures that tell their own story.

Not a revolutionary idea, by any means, **but it doubled production on the needed item,** and that is typical of resistance welding possibilities throughout the metal working industry. A Federal Press Type Welder such as the one illustrated, or related models in suitable capacities, might have similar application to, let us say . . .

Instrument Assemblies . . . Gauge Cases . . . Electrical Fixture Parts . . . Lock Assemblies . . . Automotic Valve Components . . . Automatic Switch Parts . . . Radio Chassis Components . . . a wide variety of Hardware . . . Ventilator Grilles . . . Speedometer Casings . . . Ash Trays and other Novelties . . . Two Piece Ventilated Container Caps . . . Radio Tube Assemblies . . . Oil Cleaner Assemblies or what have YOU that might be profitably converted to resistance welding if the facts were known . . .

Federal Press Type Resistance Welders (you can spot weld on them, too) are described fully in Federal Bulletin 4520. Write for your copy today. Remember, in resistance welding, the name of authority is FEDERAL.





WELDER CO. 206 Dana Street WARREN, OHIO

VERSATILE MODERN PRODUCTION TOOLS

WELDERS WITHOUT PRIORITIES

Announcement is made by Sales Manager John E. Ponkow, of The Federal Machine and Welder Company, that his company is now in a position to accept unrated orders for resistance welders. While priorities still are all that the name implies, and important war production still is the first obligation, bookings are now being made and delivery dates assigned to a large number of orders outside of the critical category, Mr. Ponkow said. Delivery schedules while far from normal, are improving steadily.

"TAKE THE WELDER TO THE JOB"

In a large sheet metal shop two men were assembling an angle iron framework which was to be the skeleton for a stainless steel kitchen sink and cabinet installation for a large hotel.

"Why don't you spot weld some of that work?" asked a man standing with the shop foreman.

"How the . . . can you horse a bunch of awkward stuff like this through a spot welder?" one of the workers retorted. "And besides, all of our work is special, we don't have enough of any one assembly for that sort of work."

"You don't have to take the job to the welder, I'll show you how to take a spot welder to the job," the visitor said, and proceeded to demonstrate the application of portable, gun-type spot welders to the job. He also proved that they did not need to have long production runs to make this type of automatic resistance welder profitable. The caller was a Federal Welding Application Engineer, and those men now are using a Federal monorail suspended portable welder with a variety of special "guns" that speed up all kinds of sheet metal fabrication in which the shop specializes.

AUTOMATIC STUD WELDER

Welding certain types of lugs and studs to small machine mounts on a production basis sometimes turns out to be a bit of a trick. One solution which has proved a time and money saver is automatic resistance welding. A Federal press-type projection welder with a special fixture and automatic feed was set up for one motor company to produce mounts complete with studs or threaded lugs (set-up interchangeable to meet production schedules) at the rate of 600 per hour.

SPOT AND/OR PROJECTION WELDERS

The difference between spot welding and projection welding, and information on how one Federal resistance welder can be used interchangeably for either method is included in a new bulletin on press-type welders just released by The Federal Machine and Welder. This is one of the most versatile of all types of resistance welders. Title is "Federal Bulletin 4520."

phone Laboratories, Inc., New York 14, N. Y.

Vice-President (Term—2 years): T. A. Boyd, Head, Fuel Dept., Research Laboratories Div., General Motors Corp., Detroit 2, Mich.

Member of Executive Committee (Term—2 years): John R. Freeman, Jr., Technical Manager, American Brass Co., Waterbury 88, Conn.; L. J. Markwardt, Assistant Director, U. S. Forest Products Laboratory, Madison 5, Wis.; Carlton H. Rose, Chemist, National Lead Co., Research Laboratories, 105 York St., Brooklyn 1, N. Y.; L. P. Spalding, Chief Research Engineer, North American Aviation, Inc., Inglewood, Calif.; William A. Zinzow, Chief Physicist, Bakelite Corp., 230 Grove St., Bloomfield, N. J.

BUYERS' GUIDE METAL INDUSTRIES

Free distribution is now being made of the 1945 Edition of the Buyers' Guide of the Metal Industries. Published by the American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio, this 108-page product directory features an extensive engineering data section.

Charts and tables in this 43-page data section present a broad range of helpful information, including trade names of tool steel and corrosion and heat-resisting alloys; the compositions and properties of magnesium alloys; nomenclature of copper alloys; fluxes for welding and brazing; machinability rating of various metals, with recommended cutting fluids for normal machining operations; metal powders—grades and data, and other information required in metals specifications and use.

Some 600 products and their manufacturers are shown in another section with a final division in the book devoted to an alphabetical listing of these manufacturers with their complete address.

Copies of the Guide will be mailed free upon request of the American Society for Metals.

SELECTING PROPER FILLER METAL

A new digest of pertinent facts about the complete line of Page electrodes and gas welding wires, written "from the buyers' stand-point" is just off the press. Each of its 33 pages contains information which will help make it easier for buyers to select the proper electrode or gas welding rod for their particular work.

Starting with the index, the booklet is designed to be of the greatest possible help in the selection of the correct welding filler metal. This index is unusual because it is based on the type and class of material which is to be welded, thus making it easier to select the electrode or gas welding rod which is best suited for welding a particular type of steel. Through the book, each page gives digested but useful data arranged for ease of reading and using. On these pages are such important facts as physical properties, analyses of the weld metal deposit, operating characteristics, recommended current ranges and other necessary information.

Copies of this DH-821 Digest can be obtained by writing to Page Steel & Wire Division, American Chain & Cable Co., Inc., Monessen, Pa.

WILSON DISTRIBUTOR

Mr. T. B. Hasler, President of Wilson Welder and Metals Co., Inc., announces that effective July 1st the Graybar Electric Co. has been appointed exclusive distributor of the Wilson brand of electrodes in the area served by Graybar's Cincinnati, Pittsburgh and Cleveland offices.

Wilson electrodes include a complete line for a.-c. and d.-c. welding of ferrous and nonferrous metals and alloys.

LINDE PLANT

The Linde Air Products Co., a Unit of Union Carbide and Carbon Corp., has announced the award of a contract to Robert E. McKee, Inc., of El Paso, Tex., for the construction of a distributing plant in Odessa, Tex., to supply this area with one of the Company's main products, Linde oxygen. Construction will begin immediately and it is expected that the plant will be completed by August 15th. Railroad service will be provided by a spur track from the Texas and Pacific Railway.

TIME IS THE BIG Saving WITH NO-SPAT

THE NON TOXIC WELDING FLUID

Saves cleaning time by keeping adjoining surfaces free of spatter. Maintains Welding Strength — 1/3 less fumes — No Monoxide — Inexpensive—Ready to use — Saves Labor — Saves Money.

SEND FOR **FREE** FOLDER

The Midland Paint & Varnish Co.
9126 Reno Avenue **Cleveland, Ohio**

Best for AC General Purpose

DUCTONE AC
(E6011 AND E6013)
WELDING RODS

Ductone AC electrodes are available again. This is the famous welding rod that was designed and manufactured especially for AC welding. DUCTONE AC rods assure low cost of operation. They have a high deposition rate and are noted for their ease in striking and maintaining an arc. Small sizes are good for thin sheet metal. Excellent for vertical and overhead welding on DC positive polarity. Extruded in all sizes from 1/16" to 1/4".

Territories Available for Distributors

Reach for DUCTONE AC *Welding Rods*

Chicago Steel and Wire Co.
103rd St. and Torrence Ave.
Chicago 17, Illinois

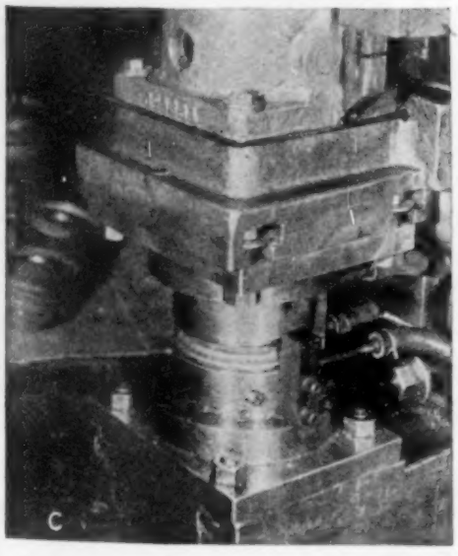
WELDING 100%

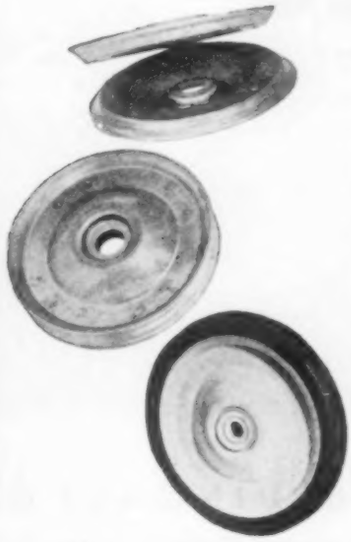
from alloy castings, installed on the standard Federal press welder, and the problem was solved. The new method, producing 1,000 wheel blanks per hour, is shown below in pictures that tell their own story.

Not a revolutionary idea, by any means, **but it doubled production on the needed item,** and that is typical of resistance welding possibilities throughout the metal working industry. A Federal Press Type Welder such as the one illustrated, or related models in suitable capacities, might have similar application to, let us say . . .

Instrument Assemblies . . . Gauge Cases . . . Electrical Fixture Parts . . . Lock Assemblies . . . Automotic Valve Components . . . Automatic Switch Parts . . . Radio Chassis Components . . . a wide variety of Hardware . . . Ventilator Grilles . . . Speedometer Casings . . . Ash Trays and other Novelties . . . Two Piece Ventilated Container Caps . . . Radio Tube Assemblies . . . Oil Cleaner Assemblies or what have YOU that might be profitably converted to resistance welding if the facts were known . . .

Federal Press Type Resistance Welders (you can spot weld on them, too) are described fully in Federal Bulletin 4520. Write for your copy today. Remember, in resistance welding, the name of authority is FEDERAL.





WELDER CO. 206 Dana Street WARREN, OHIO

VERSATILE MODERN PRODUCTION TOOLS

WELDERS WITHOUT PRIORITIES

Announcement is made by Sales Manager John E. Ponkow, of The Federal Machine and Welder Company, that his company is now in a position to accept unrated orders for resistance welders. While priorities still are all that the name implies, and important war production still is the first obligation, bookings are now being made and delivery dates assigned to a large number of orders outside of the critical category, Mr. Ponkow said. Delivery schedules while far from normal, are improving steadily.

"TAKE THE WELDER TO THE JOB"

In a large sheet metal shop two men were assembling an angle iron framework which was to be the skeleton for a stainless steel kitchen sink and cabinet installation for a large hotel.

"Why don't you spot weld some of that work?" asked a man standing with the shop foreman.

"How the . . . can you horse a bunch of awkward stuff like this through a spot welder?" one of the workers retorted. "And besides, all of our work is special, we don't have enough of any one assembly for that sort of work."

"You don't have to take the job to the welder, I'll show you how to take a spot welder to the job," the visitor said, and proceeded to demonstrate the application of portable, gun-type spot welders to the job. He also proved that they did not need to have long production runs to make this type of automatic resistance welder profitable. The caller was a Federal Welding Application Engineer, and those men now are using a Federal monorail suspended portable welder with a variety of special "guns" that speed up all kinds of sheet metal fabrication in which the shop specializes.

AUTOMATIC STUD WELDER

Welding certain types of lugs and studs to small machine mounts on a production basis sometimes turns out to be a bit of a trick. One solution which has proved a time and money saver is automatic resistance welding. A Federal press-type projection welder with a special fixture and automatic feed was set up for one motor company to produce mounts complete with studs or threaded lugs (set-up interchangeable to meet production schedules) at the rate of 600 per hour.

SPOT AND/OR PROJECTION WELDERS

The difference between spot welding and projection welding, and information on how one Federal resistance welder can be used interchangeably for either method is included in a new bulletin on press-type welders just released by The Federal Machine and Welder. This is one of the most versatile of all types of resistance welders. Title is "Federal Bulletin 4520."

LETTER TO THE EDITOR

National Research Council
2101 Constitution Avenue
Washington 25, D. C.

July 2, 1945

Dear Mr. Spraragen:

The compilation of the 8th edition of the National Research Council directory, *Industrial Research Laboratories in the United States*, is now under way. The 7th edition appeared in 1940 and contained information concerning the industrial research laboratories of 2264 companies and their subsidiaries. With five years intervening between the editions, it is expected that there will be a number of changes and it is hoped that a number of new laboratories will be added.

Although effort was made in 1940 to reach as large a number of laboratories as possible, no doubt some in each field have been inadvertently omitted. It is important that contact be made with these laboratories in compiling the forthcoming edition.

The term "research" for the purpose of the directory is construed as including investigations looking toward the improvement of products or the reduction of cost of manufacture as well as fundamental research and applied research. It does not apply to laboratories concerned only with commercial testing.

An announcement that the new edition of the directory is now being compiled would most effectively reach the laboratories in the field of welding research through a statement in your journals. We hope that you will be willing to extend us this cooperation in an early issue.

Research men should inquire of the directors of their laboratories whether questionnaires have been received, as those reporting in 1940 will have had their printed statements sent for revision. If no questionnaire has been received, one will be sent upon request to the Library, National Research Council.

The directory is issued by the National Research Council with no expectation of profit. There is no charge for the inclusion of a statement regarding a laboratory in the publication and no obligation is incurred in furnishing data.

Very truly yours,
ROSS G. HARRISON, *Chairman*

IDEAS FOR MANUFACTURERS*

The 400-page report on "Wartime Technological Developments" submitted to Congress by the subcommittee on war mobilization, of which Senator Harley M. Kilgore is chairman, ought to fire the imagination of every manufacturer, and particularly of the manufacturer who marked time in the last five years if he was not producing an essential. Open the report at random and the eye falls on item after item with rich possibilities.

An aircraft plant distributes blueprints to the proper department in a way which has reduced blueprint production by about 40%. A new chemical has been developed which makes it possible to convert cotton fiber and some cotton by-products into high-grade paper. By nickel-plating iron wires one company saves over 90% of the nickel formerly used in making incandescent lamps. Prefabricated steel-truss warehouses can withstand wind velocities and heavy snow loads far beyond requirements. There are 1400 such ideas. Many can be applied immediately after the war; others will need more research and development.

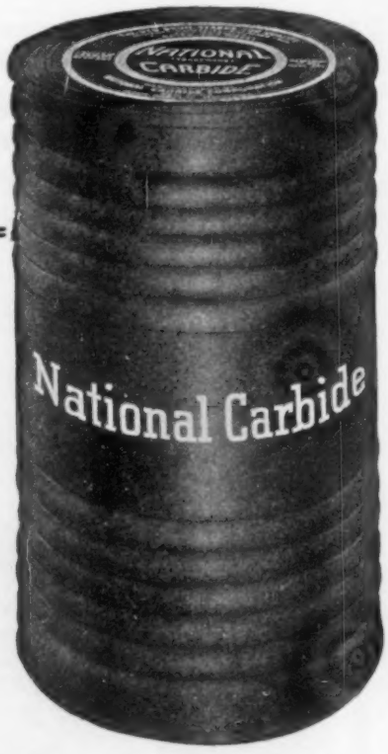
Behind this report are larger considerations. The countless ways in which electronic devices can be used, the scores of methods of adapting plywood to any type of construction, the ingenious devices that have been invented to save material, time and labor are bound to have a profound total economic effect. Will workers be displaced? The report is optimistic on that score. An invention like the automobile, radio or air-conditioning creates satellite industries and thus increases employment. Very few of the conceptions presented belong in this revolutionary class, but Senator Kilgore is convinced that "an economy of expansion will stimulate constant improvements in products and in production methods."

The main point to be driven home is the manufacturer's need of a complete review of technological developments made in the last five or six years. The Kilgore report is not complete because much still remains a military secret, but its 1400 items are more than good enough to give a resourceful business man ideas about reconversion.

* From an Editorial in New York *Times*.

National
Carbide
IN THE RED DRUM

EFFICIENT
ECONOMICAL
DEPENDABLE



FOR WELDING and CUTTING
Use National Carbide in the Red Drum
60 E. 42nd St. NATIONAL CARBIDE CORPORATION New York, N. Y.

WATER TANK

This modern elevated tank of welded construction and streamline design provides gravity water pressure in the distribution system at Lockport, Ill. It holds 200,000-gals. and is 60 ft. to bottom. The cylindrical columns are sound structurally and easy to maintain.

Welded Elevated Water Tank . . . . . .

CHICAGO BRIDGE & IRON COMPANY

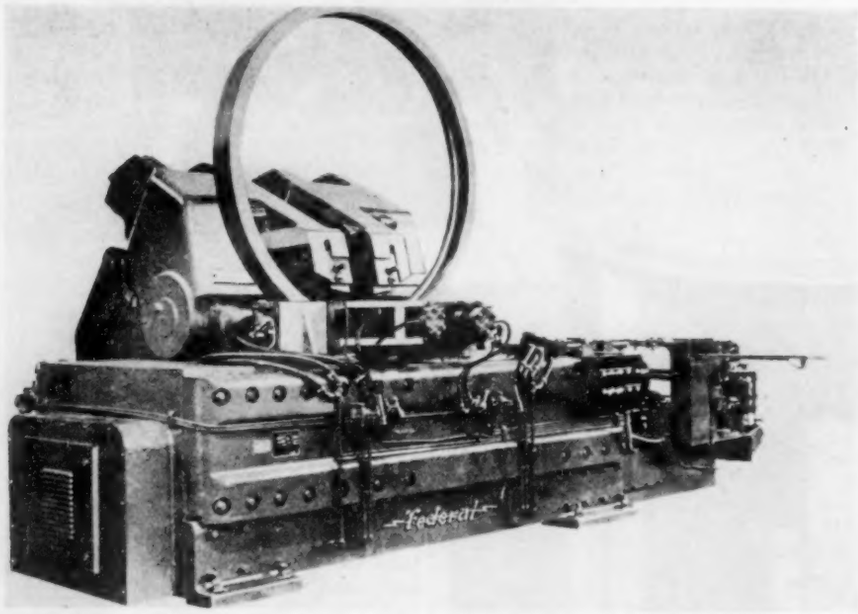
Chicago 4.....2455 McCormick Bldg.	Birmingham 1.....1907 North 50th Street	Washington 4.....703 Atlantic Bldg.
New York 6.....3398—165 Broadway Bldg.	Tulsa 3.....1654 Hunt Bldg.	Philadelphia 3.....1668-1700 Walnut Street
Cleveland 15.....2282 Guildhall Bldg.	Greenville.....York Street	Los Angeles 14.....1471 Wm. Fox Bldg.
Havana.....Edificio Abreu 402	Houston 1.....5621 Clinton Drive	San Francisco 11..1297-22 Battery Street Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM, and GREENVILLE, PA.

DESIGN FOR WELDING SPEEDS TANK PRODUCTION

A study of the manufacturing operations involved in the production of tanks discloses that the various resistance welding processes find application in important tank parts, ranging in size from engine spark plugs to half-ton turret rings. Some of the other resistance welded parts are: Crank shafts, engine valves, fuel containers, bogey wheel rims, tank treads, machine gun receivers and cannon mechanisms. Even some of the ammunition is resistance welded, the projectiles requiring the welding of a disk to the end of the projectile by one of the resistance processes.

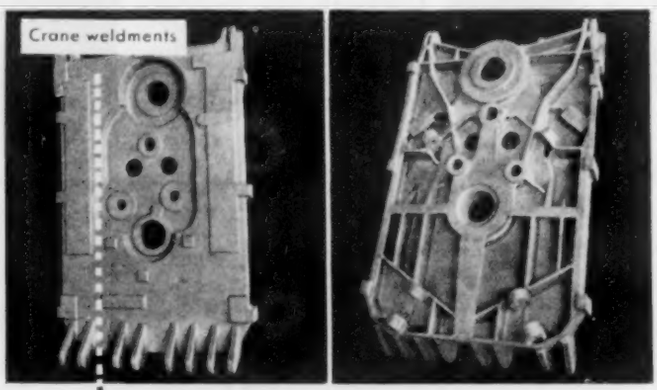
Typical of some of the heavy duty resistance welding equipment required for the production of parts is the flash welder illustrated, which was especially designed for flash butt welding heavy tank turret rings. This model is equipped with four sets of interchangeable welding dies for rings made of special high-carbon manganese alloy steel, ranging in size from $69^1/_2$ to $80^3/_4$ in outside diameter, and weighing from 700 to 1000 lb. Although the cross-sectional areas of these sizes range from $9^1/_2$ to $15^1/_2$ sq. in., the machine has capacity for welding a maximum cross-sectional area of $18^1/_2$ sq. in. of this alloy. Much larger cross sections of mild steel could be welded on the same machine. This welder is equipped with a 1000-kva. nominal rated transformer and has an available upsetting pressure of 378,000 and 1,000,000 lb. clamping pressure, operating from a 2000-lb. hydraulic pressure system. It has manual control and optional automatic control for flashing and upsetting operations. Normal production of tank turret rings is from 9 to 12 completely welded per hour. Higher speeds would be possible for welding corresponding sections of mild steel. The design of the machine is such that it can readily be adapted to the welding of many other products by suitable changes in die design.



Heavy Duty Semiautomatic Flash Butt Welder, Especially Designed for Flash Butt Welding Heavy Army Tank Turret Rings

AMPCO ISSUES BULLETIN

"Welded Assemblies Fabricated at Ampco" is the title of a new bulletin just issued by Ampco Metal, Inc., Milwaukee, Wis. The bulletin describes the facilities of Ampco for producing assemblies made of bronze sheet, castings or extruded parts



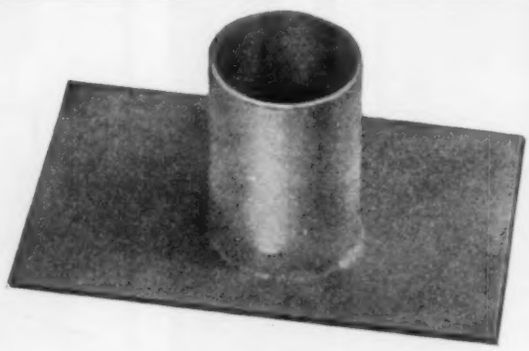
WONDERS NEVER CEASE!

That's a fact . . . in a modern fabricating plant. Take the crane weldments shown above . . . 5100 lbs. of complicated subassemblies . . . each a fair engineering and welding project in itself.

Submit your drawings. Consult our Engineers.

Work of this character features operations at United, where 32 years of experience and the latest in equipment are joined to produce welded products and parts with precision, speed and economy.

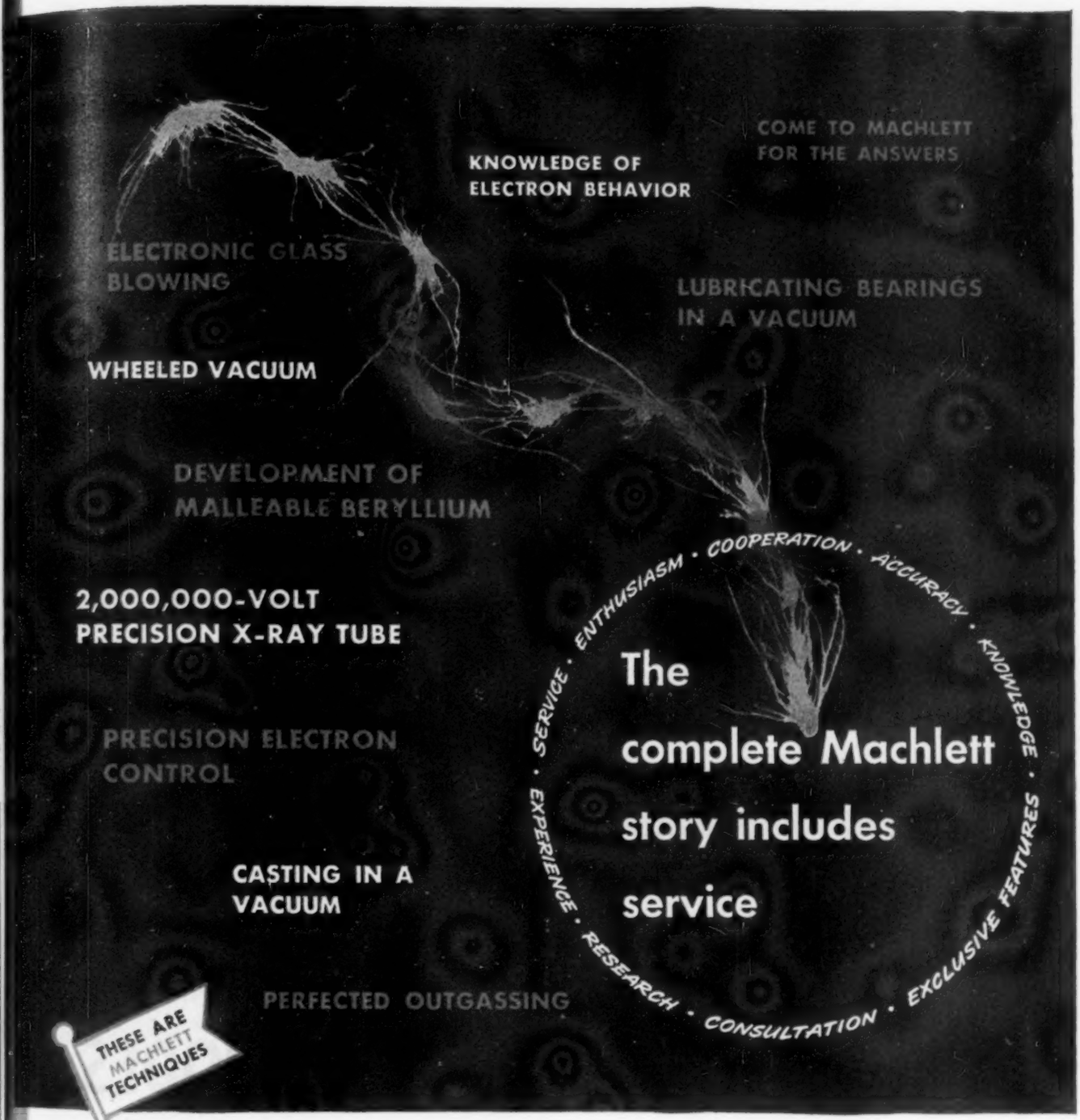
THE UNITED WELDING CO.
MIDDLETOWN, OHIO
WELDING FABRICATORS OF MODERN DESIGNS
SINCE 1913



BRAZE RATHER THAN WELD ALUMINUM

The Kre-Co Aluminum Brazing Process makes brazing possible at a temperature safely below the melting point of the parent metal. Makes a perfect bond even with thin gauge aluminum. Used with a 5% Silicon Rod. Bulletin A 2 contains valuable information you should have.

KRE-CO MULTICHEMIC FLUX
DIVISION OF
CHARLES W. KRIEG CO.
52-60 Dickerson St. Newark 4, N.J.


KNOWLEDGE OF ELECTRON BEHAVIOR
COME TO MACHLETT FOR THE ANSWERS
ELECTRONIC GLASS BLOWING
LUBRICATING BEARINGS IN A VACUUM
WHEELED VACUUM
DEVELOPMENT OF MALLEABLE BERYLLIUM
2,000,000-VOLT PRECISION X-RAY TUBE
PRECISION ELECTRON CONTROL
CASTING IN A VACUUM
PERFECTED OUTGASSING
THESE ARE MACHLETT TECHNIQUES
SERVICE · ENTHUSIASM · COOPERATION · ACCURACY · KNOWLEDGE · EXCLUSIVE FEATURES · CONSULTATION · RESEARCH · EXPERIENCE ·
The complete Machlett story includes service

The above ten Machlett techniques reflect only a part of one side of this organization — that of technical capability.

It takes much more than even the highest techniques to make a business great. There is also required a thorough knowledge of customers' requirements, and that conscientious, painstaking, continuing meeting of them called "service."

Just as there is the most intimate relationship between an electron tube and the equipment with which it is connected, so there is a close and constant contact with our customers. With them we are never in competition, and thus we may be, and often are, called upon to do design and development work, to live with tube and equipment problems, and cooperate in solving them. We often follow through all the way to the ultimate users, to make certain of their satisfaction and see that conditions of use are such as to assure optimum results and economy. It is a long-established Machlett practice not merely to accept but to seek out every opportunity to serve. Thus, Machlett customers obtain much more than the best possible tubes.

When you need a medical or industrial X-ray tube, or a radio or industrial oscillator, amplifier or rectifier, it will pay you to choose a Machlett. Write for information as to available types, identifying the associated equipment and nature of use. Machlett Laboratories, Inc., Springdale, Connecticut.

MACHLETT

RAY TUBES SINCE 1897

TODAY THEIR LARGEST MAKER

welded with Ampco-Trode aluminum bronze weldrod. Illustrations show the type of assemblies produced and indicate the versatility of the organization.

The production of fabricated assemblies is a service to Ampco customers who need a reliable source for subassemblies.

McLAUGHLIN HEAD OF NEW TUBE TURNS DIVISION

Carl B. McLaughlin will head up the recently established Engineering Service Division of Tube Turns, Inc., Louisville, Ky., it is announced by John G. Seiler, the firm's vice-president in charge of sales. The division is rapidly developing new applications for Tube-Turn welding fittings.

McLaughlin formerly was associated with Tube Turns' Pittsburgh office. A native of Jacksonville, Ill., he graduated from the University of Illinois in 1931 and was a metallurgist-engineer with the U. S. Steel Corp. before joining Tube Turns in 1943. Mr. McLaughlin is a member of the AMERICAN WELDING SOCIETY.

Carl B. McLaughlin

AMPCO APPOINTS FOUR WELDROD DISTRIBUTORS

Ampco Metal, Inc., Milwaukee 4, Wis., announces that four new distributors have been added to handle the sale of Ampco-Trode coated aluminum bronze weldrod.

The Cameron & Barkley Co., with headquarters office at Charleston, S. C., has been franchised for the State of Florida with branches in Orlando, Miami, Jacksonville and Tampa.

Mobile Welding Supply Co. at Mobile, Ala., will cover the N. W. tip of Florida, the South half of Alabama and several counties in S. E. Mississippi.

Delta Oxygen Co., at Memphis, Tenn., will operate in parts of four states covering Western Tennessee and Kentucky, Northern half of Mississippi and N. E. Arkansas.

WILLIAMS HONORED

In tribute to his leadership in advancing industrial science, Clyde Williams, Director of Battelle Memorial Institute, Columbus, Ohio, was presented the degree of Doctor of Science at recent convocation ceremonies of the Case School of Applied Science, Cleveland, Ohio.

Clyde Williams

The degree was presented by Dr. William E. Wickenden, President of Case, who cited Mr. Williams' accomplishments in research administration and in directing

Announcing

REXALOY OVERLAY ELECTRODES

for either AC *or* DC *machines*

Designed for "toughness" in resisting abrasion—there is a Rexaloy Electrode for every type of overlay requirement.

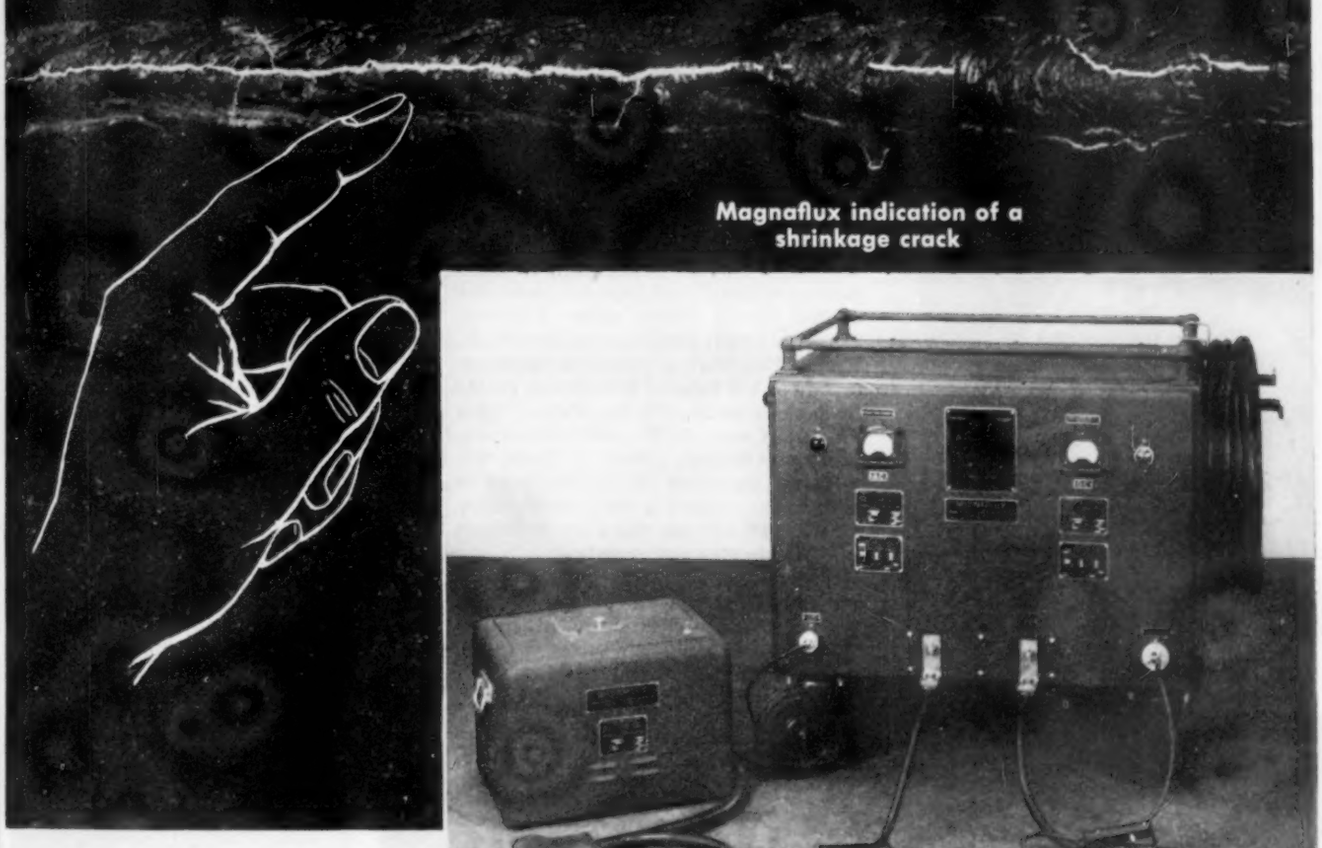
★

For complete information, see your jobber or write to

THE SIGHT FEED GENERATOR CO., RICHMOND, IND.

MAGNAFLUX*...

"puts the finger" on welding flaws



Magnaflux indication of a shrinkage crack

NEW KH-2 MOBILE UNIT

Welds, that look perfect to unaided visual inspection, often conceal a hidden crack or other dangerous discontinuity. If such flaws exist, Magnaflux will point them out. Magnaflux indications are positive, easily interpreted, inescapable.

Magnaflux provides quality control for welding shops and other metal processing operations. In addition to thermal cracks, Magnaflux detects lack of penetration and fusion, slag inclusions and other defects that cause rejections.

Because it is non-destructive, magnetic particle inspection makes it possible to inspect *every* weld at a speed which keeps pace with production. Shape, location and size of unseen flaws are spot-lighted in finely divided metallic particles.

The new KH-2 Magnaflux unit, illustrated above with the XB-2A Powder Blower provides low-voltage, high-amperage outputs—both AC and half-wave rectified current, for either AC or DC magnetization—and also demagnetization after inspection.

Build confidence in your weldments by thorough use of Magnaflux. Write today for additional information and free copy of "Routine Inspection and Salvage of Machinery Weldments" by James W. Owens.

*Magnaflux, Registered U. S. Patent Office, a trade mark of the Magnaflux Corporation applied to its equipment and materials for magnetic particle inspection.

MAGNAFLUX CORPORATION

5922 Northwest Highway, Chicago 31, Illinois

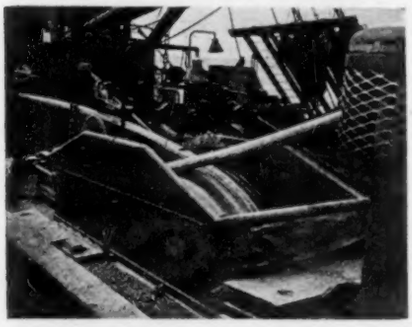
NEW YORK DETROIT DALLAS LOS ANGELES CLEVELAND BIRMINGHAM

the activities of the War Metallurgy Committee of the National Academy of Sciences and the National Research Council.

Louisiana Welding Supply Co. at Baton Rouge, La., formerly operating as an associate distributor for Gulf Welding Equipment Co., New Orleans, takes over the South Central part of Louisiana.

"OPERATION PLUTO": THE STORY OF THE CHANNEL PIPE LINE

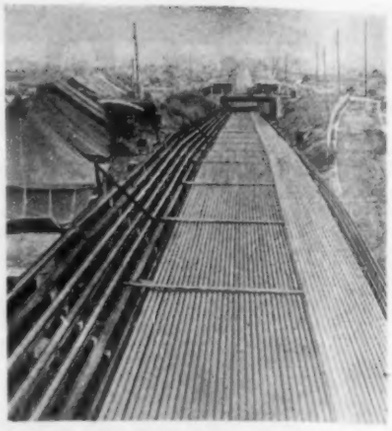
From Aug. 12, 1944, to May 8, 1945, about 120,000,000 gal. of gasoline reached the Anglo-American Armies in Europe via the pipe-line system laid under the English Channel by British engineers in cooperation with the British Navy. One million gallons daily still reach France by way of 20 undersea pipe lines. Sixteen of these run from Dungeness, on the southeast coast of England, to Boulogne and four from the Isle of Wight to Cherbourg, and are thence carried via high-pressure gasoline lines to the Rhine. This vast engineering feat was called "Operation Pluto," meaning "Pipe Line Under the Ocean," and guaranteed uninterrupted delivery of bulk petroleum, usually needing a special harbor and dock and extensive storage facilities, across the beaches, making it invulnerable from air, surface or submarine attack, and completely independent of the weather.



The 3-In. HAIS Cable Passing Round the Cable Drum of the Liberty Ship "Latimer" During the Laying Operation. This Shows Flexibility of This Continuous-Built Pipe

While the British Pluto project was under way, the United States Army was working on a similar idea. After discussions between the respective authorities, it was agreed that efforts should be concentrated on Pluto, and United States authorities magnanimously cooperated fully in many directions. General Eisenhower and his chief officers took an active interest in Pluto's development, and a unit of the United States Army Engineers Corps, under the direction of Colonel A. K. Easton, New York, arranged for the manufacture of 140 miles of HAIS cable by the General Cable Co., Phelps Dodge Copper Products Corp., the General Electric Co. and the Okonite Callender Cable Co. With the exception of the 140 miles of cable manufactured in the United States, the Channel pipe line was a purely British operation in plan and execution.

It was Lord Louis Mountbatten, then head of Combined Operations, who in April 1942, asked Geoffrey Lloyd, British Minister of Petroleum Warfare, if an oil pipe line could be laid across the English Channel. The experts were doubtful, but A. C. Hartley, Chief Engineer of the Anglo-Iranian Oil Co., who had used 3-in. high-pressure pipe lines in Persia, suggested a pipe line something like a submarine electric power cable without cores and insulation, which could be laid across the Channel in a few hours from cable-laying ships.



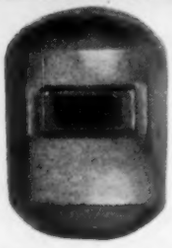
HAMEL Pipe Stored in Three-Quarter Mile Lengths Ready for Winding on the Conun-Drums, the Huge Seagoing "Bobbins" Which Laid the Pipelines by Rolling it Off as They Were Towed Across the Channel. About 200 Miles of Pipe Can Be Seen in This Picture

By working day and night over two week ends, technicians of the firm of Siemens and Henleys completed the full-scale

For Greater Safety ★ Superior Welding

USE G-E WELDING ACCESSORIES

VENTILATED HELMET



(Cat. No. 87X578) Equipped with a crown sheet for skull protection, this helmet features screened ventilators which provide cool comfort and prevent fogging of the glass. Included also are eye-protective lens, lens gasket, clear cover glass, adjustable chin rest, head gear, snap-on sweatband.

(List Price $6.50)

TREATED COVER GLASS

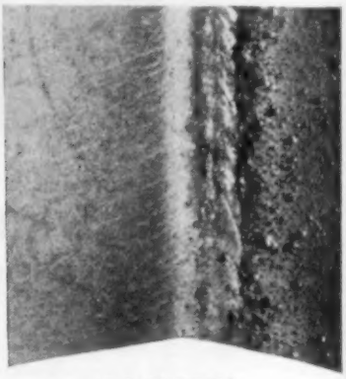
(Cat. No. 98X349) Coated on both sides with a tough, transparent, moistureproof compound this cover glass helps to maintain clear vision and is highly resistant to weld-spatter. Efficiency of coating gives this glass many times the life of an untreated glass.

(List Price $0.10)

FILLET-WELD GAGE

(Cat. No. 92X512) A necessary tool for both operators and inspectors, this handy fillet-weld gage provides a quick, accurate means of gaging fillets which have a straight, concave, or convex contour of the following sizes: ¼ in., 5/16 in., ⅜ in., 7/16 in., ½ in. and 5/8 in.

(List Price $1.25)



G-E GLYPTAL*

No. 1294—Weld-spatter Preventive Coating. A single coating of No. 1294 prevents adhesion of weld-spatter for either singlepass or multipass welds. Especially suitable when fabricating stainless or special alloy steels.

(List Price per gal. $1.80)

*Trade-mark Reg. U.S. Pat. Off.

OTHER G-E WELDING ACCESSORIES

Gloves • Lenses

Goggles • Slag brushes

Cable connectors

Electrode holders

Leather clothing

General Electric Company
Schenectady 5, N. Y.

BUY WAR BONDS

GENERAL ELECTRIC

672-62-8748

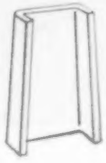
"Fluid and Flexible"... *he says*

THAT, ZHUKOV, is also the battle cry of manufacturers using Arc Welding to win business victories.

WHEN THE SALES DEPT. SAYS:
"We've got to trim the cost of our product or get trimmed in the field."

THEN THE SHOP DEPT. SHOULD REPLY:
"O.K., let's go after parts such as this 95¢ cab support—

1 Cut a plate and bend into a channel so . . .



2 Cut a base plate so . . .

3 Cut 3 braces so . . .

4 Use a stud so . . .

5 Assemble the parts in a jig and weld

Total cost of welded steel support, 52¢ . . .

SAVING 43¢ each."

The Lincoln Engineer nearby will gladly help you develop your strategy along the fluid and flexible lines of welded design. Studies in Machine Design free on request. Ask for them on your business letterhead.

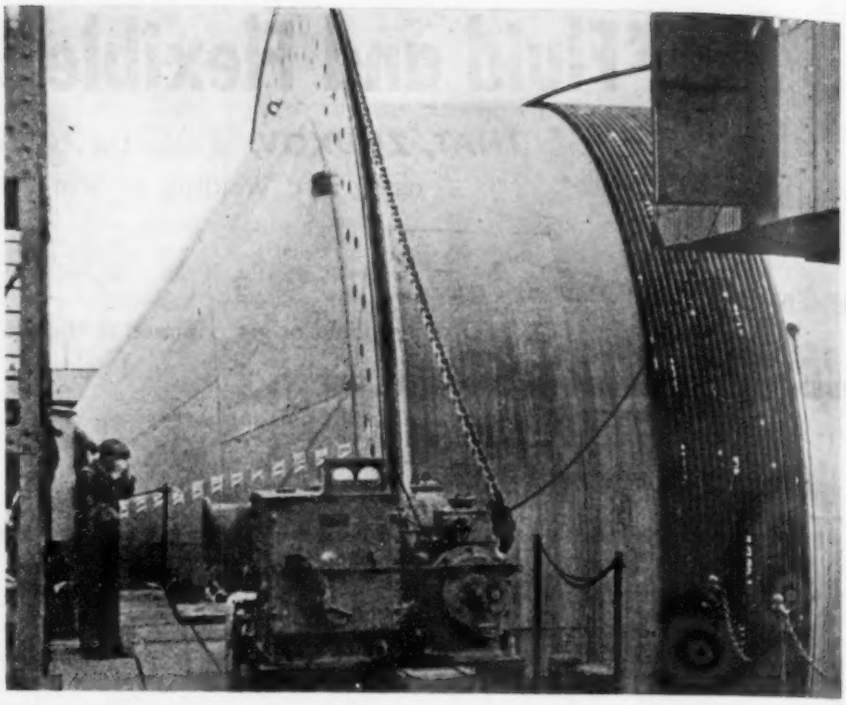
THE LINCOLN ELECTRIC COMPANY • Dept. P-1, Cleveland 1, Ohio

America's greatest natural **recourse**

ARC WELDING

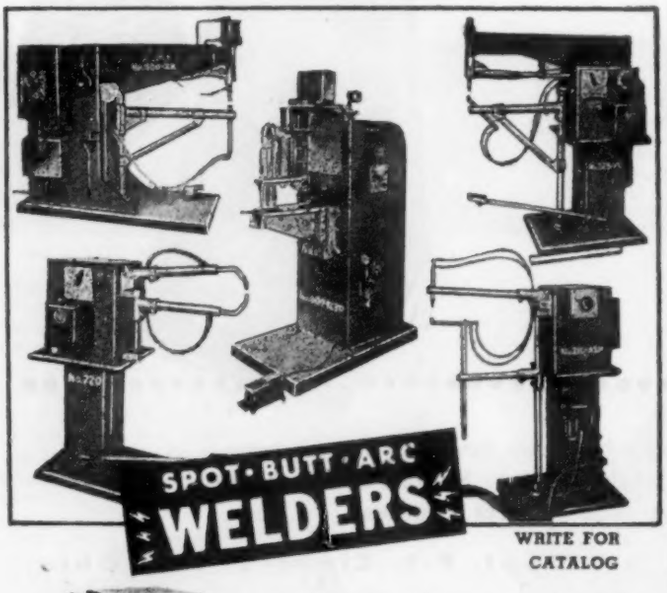
order for several hundred of yards of this pipe line to be laid in the Thames from a cable ship loaned by the British Post Office. The results were so successful that Prime Minister Churchill gave the scheme his blessing and two 30-mile lengths of cable were ordered to the original 2-in. diameter, so that full-scale trials could be held in Bristol Channel, where the currents and other conditions approximated most closely those found in the English Channel. Subsequently, the cable diameters were increased to 3 in. and strengthened for working pressures in excess of 1200 psi. Eight months after Hartley's idea originated, when half a gale was blowing Bristol Channel, the experimental cable was laid by H.M.S. Holdfast, originally a coaster which had been fitted with gear for transporting this unusually heavy cable, and gasoline was delivered from Swansea to Ilfracombe. The fact that the cable was hollow increased the difficulties, since it was liable to kink and so stop the oil flow. The cables were therefore laid full of water, which kept them inflated. This pipeline was called the HAIS (Hartley-Anglo-Iranian-Siemens).

Meanwhile another pipe line was invented by B. J. Ellis, Chief Oilfields Engineer of the Burma Oil Co., and H. A. Hammick, Chief Engineer of the Iraq Petroleum Co. This second pipe line named "Hamel," was composed of 20-ft. lengths of 3-in. diameter steel pipe which could be welded automatically into any length and could be wound on to a drum like thread on a spool, if the drum were 30 or more ft.



Drums for Carrying the Steel Pipe Were Known as "Conuns" (H.M.S. Conundrums). This "Conun" Is Being Wound with One Continuous Length of Hamel Pipe. Later It Was Towed Across the Channel by the Royal Navy Laying the Pipe as it Went

in diameter. To use this, the Admiralty's Director of Naval Construction designed H.M.S. Persephone, converted from a hopper barge to a craft with a great wheel rotating in trunnions on her deck and capable of carrying many miles of the 3-in. Hamel pipe and paying it into the sea. From this a second idea was developed—a floating drum capable of carrying the full length of pipe which might be required for



WRITE FOR CATALOG

We manufacture a complete line of resistance spot welders from ¼ to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

TRANSFORMERS OF ALL TYPES

WE INVITE CONTRACT SPOT WELDING IN LARGE OR SMALL QUANTITIES.

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Degreasing Steel to Assure Better Welds?

A sound practice to help you secure strong, uniform welds is THOROUGH cleaning of steel plates, sheets, forgings or castings before the welding operation. You can do this effectively with specialized Oakite cleaning materials . . . materials that will help you produce better and more welds in less time.

Scientifically-formulated Oakite degreasing and descaling agents completely remove oil, grease, drawing compound, heat scale, rust or other foreign matter. FREE information gladly sent on request.

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OAKITE MATERIALS · METHODS · SERVICE — Trusty Friends for Victory — CLEANING FOR EVERY CLEANING REQUIREMENT

FEWER HEADACHES FOR YOU WITH THIS FERRO MANGANESE

Is your manganese pick-up in the weld metal below par? Are you having trouble maintaining uniformly good results? Then we suggest you try Foote Ferro Manganese.

VARIATIONS MINIMIZED

Foote Ferro Manganese is ground to conform with screen specifications containing limiting maximum and minimum screens. Thus welding electrode manufacturers are assured a source of ferro manganese with consistent and reliable chemical and particle size characteristics. Other factors remaining constant, this allows full realization of the benefits which may be derived from a controlled product, namely, minimum variation in manufacturing processes, welding characteristics, and physical properties of deposited metal.

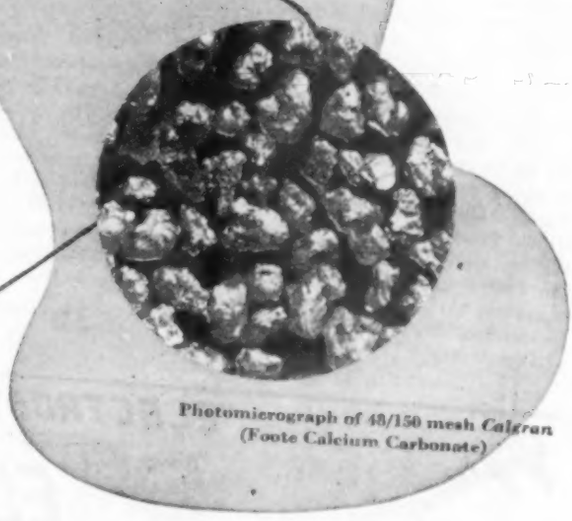
MAXIMUM METAL PICK-UP

For optimum manganese arc transfer efficiency, relatively coarse granulations of ferro manganese are recommended. Tests by others and by our own welding laboratory show that manganese metal pick-up is greater when transferred through the arc by coarse particles. Reason: coarse particles have less exposed surface and therefore are less susceptible to oxidation. For the same reason—less surface per unit of weight—coarse particles minimize gassing characteristics when incorporated in electrode coating batches for extrusion.

See these advantages for yourself. Get in touch with us today for experimental samples and prices.

OURS IS A BIG SMALL WORLD

One of the most essential of the services Foote renders to industry is the grinding of metals, ores and minerals. Raw materials from the remotest corners of the globe come to Foote for processing. The particle sizes in which Foote delivers them can often only be appreciated with the aid of a strong lens. From the big world of resources we make the small world of useful particles.



Photomicrograph of 40/150 mesh *Calgran* (Foote Calcium Carbonate)

Foote
MINERAL COMPANY
A Step Ahead in Industrial Ores and Chemicals

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Home Office: 1611 SUMMER STREET, PHILADELPHIA 3, PA.
West Coast Repr.: Griffin Chemical Co., San Francisco, Calif.

the Channel crossing, and which could be towed by tugs like a large bobbin paying off the pipe as it went.

Within a few months, a special factory at Tilbury, in the Thames Estuary, was equipped for welding 20-ft. lengths of the Hamel pipe 4000-ft. lengths at a rate of 10 miles daily, with facilities for storing the lengths to a total of 350 miles a day. Shortly afterwards a duplicate factory was established in case the first should be bombed.

The floating drums, called H.M.S. Conundrums (or "Conuns" for short) were moored in deep water at the end of the pipe-racks, so that the 4000-ft. lengths might be welded into a continuous length of 30 or more miles, and wound on to the Conuns while they rotated. A Conun is 90 ft. long, over 50 ft. in diameter overall, and when fully wound weighs 1600 tons—the weight of a destroyer. It can carry 70 miles of pipe line. The drum around which the pipe is wound is 40 ft. in diameter and 60 ft. long.

After the successful trials of the HAIS cable in April 1943, Geoffrey Lloyd arranged that the manufacture of HAIS cable and Hamel pipe, and the coordination of the whole scheme, together with provision of pumping stations on the English shore, should be the responsibility of Britain's Petroleum Warfare Department. The work then developed in conjunction with the Admiralty Department of Miscellaneous Weapons Development, while the Royal Navy accepted the responsibility of laying the pipes at sea. Thus Force Pluto was formed under Captain J. F. Hutchings of the Royal Navy, composed of ships of all sizes from 10,000 tonners down to barges and motorboats manned by British Merchant Navy seamen. The Force was placed under the command of Admiral Sir Bertram Ramsey, Allied Naval Commander.

Force Pluto's main base was Southampton, England, with a secondary base at Tilbury. The Force numbered 100 British Merchant Navy officers and 1000 men. In addition to H.M.S. Holdfast, three merchantmen were fitted with the cable-laying machinery. Two could carry 100 miles and one, 30 miles of HAIS cable. Thames barges were converted for handling the cable at the shore ends, where large ships could not operate. Six Conuns handled the Hamel pipe. New pipe lines were run from the British system to take the gasoline to the coast, and special high-pressure pumping stations were cleverly camouflaged. One of these was in a row of blitzed houses at Sandown, on the Isle of Wight; another was in an old fort built in the 1860's against possible invasion by Napoleon III; and others were in a modern amusement park and in seaside villas at Dungeness.

"Operation Pluto" began as soon as the mines had been swept to the approaches to the tip of Cherbourg Peninsula. The lines running from the Isle of Wight to Cherbourg took 10 hours to lay and conveyed gasoline to the United States armies. The lines established as soon as Boulogne was captured, from Dungeness to Boulogne, too 5 hours to lay and transported gasoline to the British 21st Army Group. Men of the Royal Army Service Corps pumped oil to cleverly concealed pumping stations on the French coast, frequently in rough weather, having to wade up to their necks to bring in the end of the line from the ships. An R.A.S.C. petroleum unit also maintains direct contact with the Trench terminals by cross-Channel wireless telephone, thereby instantly detecting and reporting variations in the quantities delivered.

Paying tribute to this British engineering feat, Prime Minister Churchill said: "A large part of the Allied Expeditionary Force has been supplied with petrol by this unique method, which provides for petroleum the same kind of facilities upon a hostile shore that the Mulberry (prefabricated) harbors provided for general military stores. Operation Pluto is a wholly British achievement and a feat of amphibious engineering skill of which we may well be proud."

General Dwight D. Eisenhower expressed his "warm appreciation of the work the Pluto pipe lines have done insupplying United States as well as British forces in their drive into Germany."

WELDING WIRE DOWN FROM PEAK OUTPUT*

Estimated production of steel welding wire declined to 932,400,000 lb. in 1944, a drop of 20% from the 1943 record output of 1,166,400,000 lb.

The lower volume of shipbuilding last year mainly accounted for the drop in welding wire output. Despite the decline, however, the 1944 production is the second highest for this wire and is nearly four times the 1940 output.

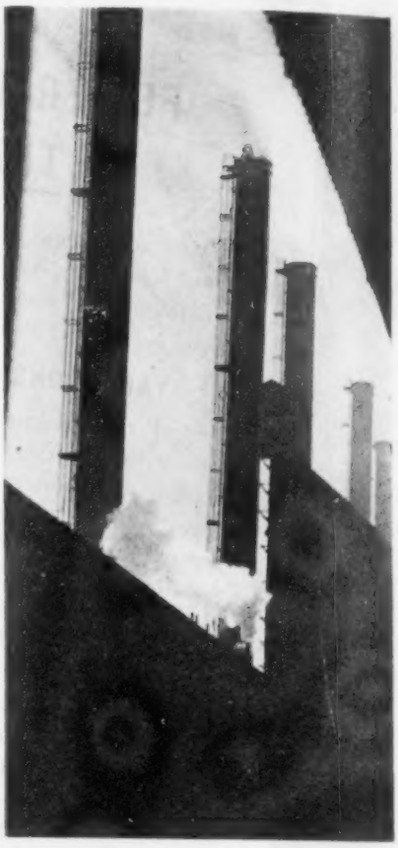
Over 13 lb. of welding wire were made last year for each ton of finished steel produced. This ratio is also the second highest, being exceeded only by the 1943 ratio of over 17 lb. of wire per ton of finished steel.

The output of steel welding wire increased rapidly before the war and rose even more rapidly during the war period. From 1932 to 1940 the output rose an average of 30,000,000 lb. per year. Since then, the average increase has been 173,000,000 lb. annually—six times the prewar rate of growth.

* Reprinted from June 1945 issue of "Steel Facts."

WELDED SMOKESTACKS

Arc-welded smokestacks, replacing those of conventional design tower over this industrial scene and signify the importance of the electric arc process in steel mill maintenance.



Courtesy The Lincoln Electric Co., Cleveland, Ohio, and Republic Steel Corp.

THREE SPECIAL WELDING COURSES BEING CONDUCTED AT LINCOLN ELECTRIC

Three new, specialized courses in arc welding are announced by the Lincoln Electric Co., Cleveland, Ohio, which are designed to increase the student's knowledge of the shielded arc process as applied to specific metals and structures.

The courses consists of one two-week training period to instruct enrollees in the technique of arc welding the common steel alloys and nonferrous metals. A second course of one week's duration is devoted to instruction in welding sheet metal in thicknesses of from 12 to 20 gage. A third two-week course is intended to train students in the welding of pipe in diameters of from 2 to 10 in.

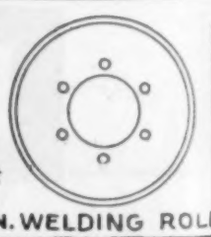
Those now enrolled in these postgraduate courses of instruction and who

"ELECTROLOY" for RESISTANCE WELDING

Butt
Flash
Spot
Seam
Projection

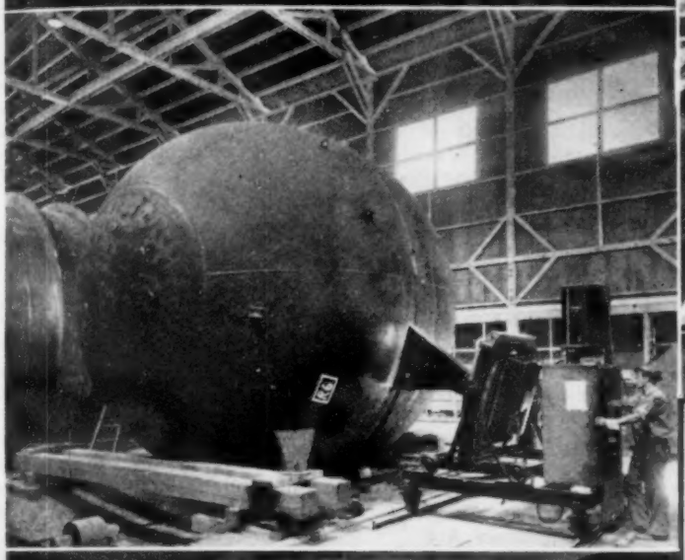
ELECTROLOY

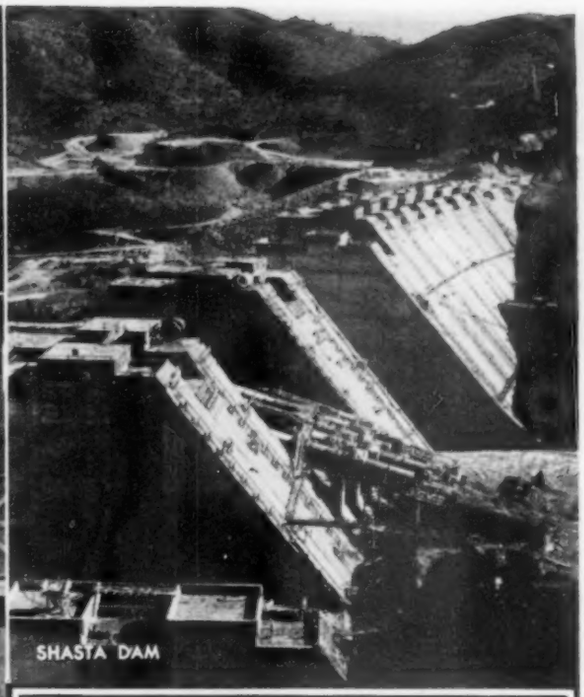
Catalog and prices on request



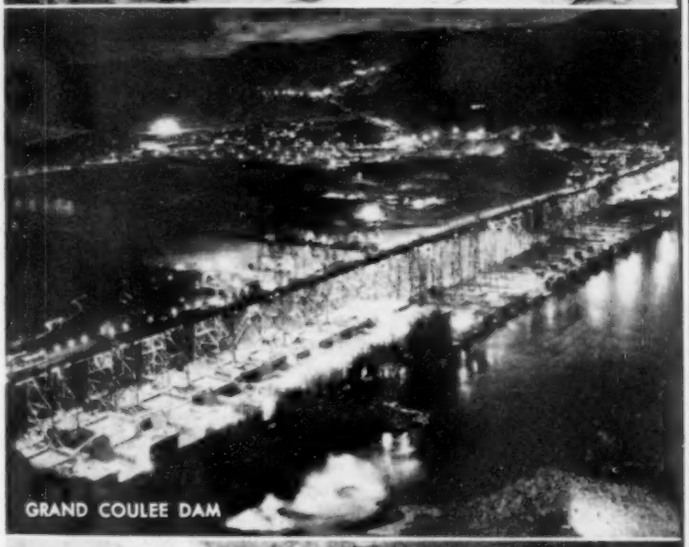
THE ELECTROLOY CO. INC. 1600 SEAVIEW AVE. BRIDGEPORT, CONN.

WHERE WELDS MUST BE RIGHT··· INDUSTRY DEPENDS ON G.E. X-RAY





SHASTA DAM



GRAND COULEE DAM

BOULDER DAM

Where weldment strength . . . as great as mechanical skill can accomplish . . . is an absolute requisite, G-E X-Ray inspection insures that strength.

Used for the inspection of welded penstocks, G-E X-Ray Industrial Units have figured prominently in the construction of most of the nation's great dams.

Leading fabricators of welded tanks for storing volatile liquids and gases, and liquids of low volatility utilize G-E X-Ray Units—radiographically check every inch of welded seam to determine fitness.

Repair welding is saving many concerns incalculable sums annually . . . and they rely on G-E X-Ray for positive proof of a job done right.

And countless plants are finding G-E X-Ray an invaluable aid in qualifying welders, checking critically stressed locations of welded structural units, determining experimental weld quality, and establishing correct welding procedure.

G-E X-Ray industrial engineers are anxious to help you realize the benefits x-ray offers your industry. Write or wire today; to Department N88.

1895 OUR FIFTIETH YEAR OF SERVICE 1945

GENERAL ELECTRIC X-RAY CORPORATION

175 W. JACKSON BLVD. CHICAGO 4, ILL., U. S. A.

L. W. (Pop) TRAHAN Says

"ALL WELDERS IN OUR SHIPYARD USE THERMACOTE LENS AND GIVE THEM TOP RATING. WITH THERMACOTE LENS YOU CAN BURN THE RODS ALL DAY LONG AND NOT HAVE ANY TROUBLE WITH THE SPLATTER."

"Pop" Trahan has been welding since 1926. He worked three years as railroad boiler maker. For ten years he has been building ships for Levingston Shipyards, Texas. "Pop" knows the electric welding game from A to Z.

THERMACOTE CO.
NEWARK CHICAGO
PORTLAND LOS ANGELES

are already skilled in the welding of mild steel, represent a wide variety of industries throughout the country.

The courses are under the supervision and direction of Arthur Madson, veteran Lincoln instructor at the company's plant, where a school for the training of men and women in the art of arc welding has been conducted uninterruptedly for nearly 30 years. Being the oldest school of its kind in continuous existence, it has trained over 25,000 people in this rapidly growing profession.

WELDING LIBRARY

To assemble in one place all the important literature on welding—this is the objective of the A. F. Davis Welding Library at the Ohio State University, in Columbus.

Established in 1942, the Library already includes one of the most extensive collections on welding in the world. On its shelves are more than 1000 books, including volumes on metallurgy, designing for welded construction, welding techniques and procedures, properties of weld metals, standard welding handbooks, welding magazines, the original award studies of The James F. Lincoln Arc Welding Foundation, patents relating to welding and many other subjects.

The Library is named for its donor, A. F. Davis, vice-president and secretary of the Lincoln Electric Co., Cleveland, Ohio. Mr. Davis has spent over 30 years in the welding industry. During this time he has seen welding processes develop from little more than laboratory experiments into a large industry.

Appropriately, the A. F. Davis Welding Library is located at the Ohio State University, the only university offering a 4-year course in Welding Engineering. Here it will be of inestimable value to both undergraduates and graduate students preparing for careers in this field.

The facilities of the Library are also offered to industrial designers, engineers, technicians and others interested in research or information on the various forms of welding and their application to design, construction, manufacture or maintenance of metal products and structures.

Welding has developed so rapidly and it is now so widely used in industry that all possible knowledge of its application to design and construction is vital to its most efficient utilization. Just as welding has made notable contributions to the nation's war effort, so also it may be expected to find increasing usefulness in the years ahead. Study and investigation will help extend its benefits.

The A. F. Davis Welding Library invites the assistance of the industry in extending its collection.

In accordance with the donor's wish that the Library contain every important book, manuscript, article or document relating to welding, engineers doing original research are invited to send their papers to the Library for permanent filing and for use by industry in future years.

Copies of over 10,000 patents concerning welding equipment and the patented applications of welding to products or structures are now on file, offering one of the most extensive reference collections available in the Middle West from which patent researchers may obtain information. It is desired to make this collection of patents the most complete one in the world. To accomplish this end, friends of the Library are urged to send to the Librarian the patent number of any patents pertaining to welding, welded equipment, welded machine design, welded structural design or any welding application.

All such patents suggested will be checked against present holdings and if not now included will be obtained.

Visitors to the Library are welcomed, and communications about its work are invited. Inquiries may be directed to the Davis Welding Library, The Ohio State University, Columbus 10, Ohio.

NEW AIRCO ELECTRODE CATALOG

Air Reduction, leading manufacturer of welding equipment and supplies, is now distributing a new electrode catalog which is said to be one of the most complete and elaborate books of its kind ever issued.

Beginning with a full color page showing color markings of various electrodes cataloged, the 56-page book contains a combined electrode selector chart and index, illustrated sections on Mechanical Properties and Testing and on Approvals.

The entire line of Airco Electrodes for welding mild steel, alloy steels, stainless steels, galvanized sheet steel, aluminum and other nonferrous metals and for hardfacing is covered with complete descriptions and details of applications, welding procedure, mechanical properties, chemical analyses and specifications. Various types of fillet welds made with many of the electrodes cataloged are also illustrated and a reference section at the back of the book offers information on such subjects as "Plate Edge Preparation," "Estimating Electrode Requirements," "Welding Symbols," "Hardness Conversion Table" and "Glossary of Welding Terms."

The book is attractively printed in two colors with full-color cover and the entire arrangement is calculated to make it easy to use.

Copies may be obtained from Air Reduction, 60 E. 42nd St., New York 17, N. Y., or from any Airco office.

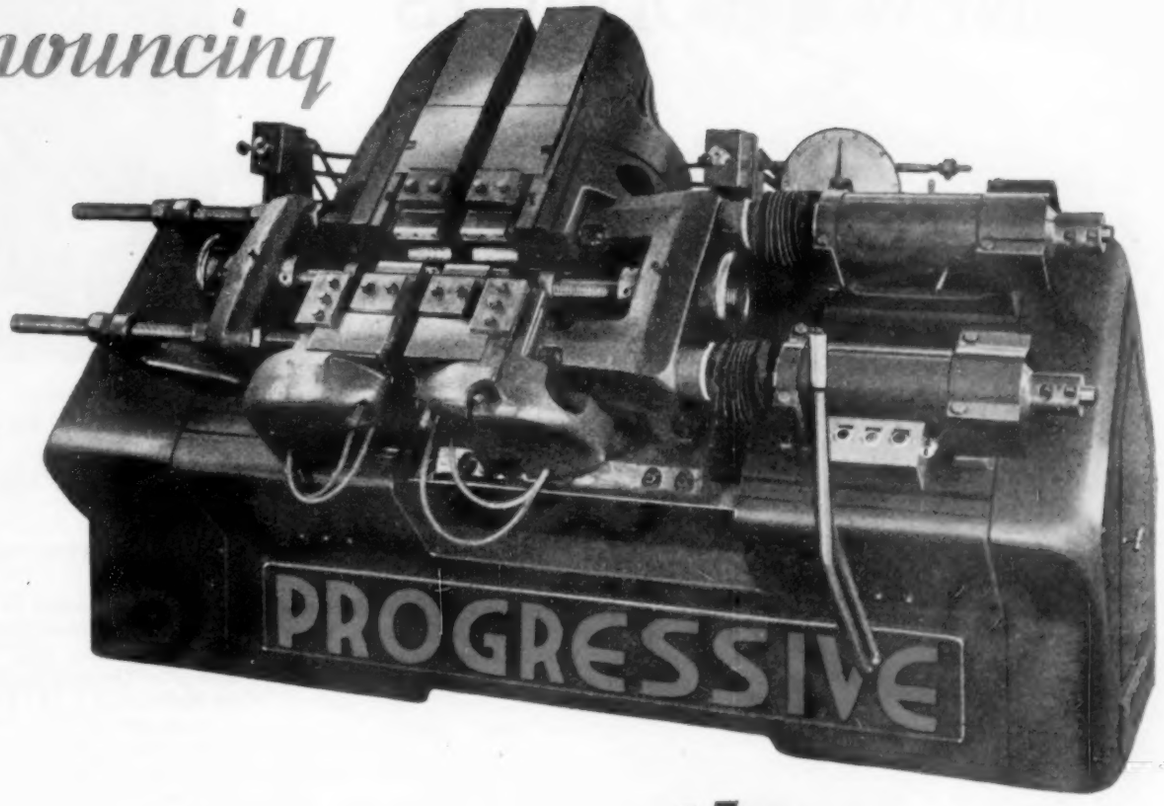
POSTWAR PRODUCTION

In line with its postwar production plans, the Eutectic Welding Alloys Co., has recently issued a 4-page folder entitled "Production Ideas." This attractive folder gives a complete discussion of Eutectic's plans in the postwar period as well as a discussion of the application of its special alloys in various production fields.

Many photographs and technical diagrams illustrate the jobs that will be done in the postwar period. There is also a listing of the 47 Eutectic Welding Alloys and how they can be applied in the various fields of production.

A copy of this attractive 4-page folder may be secured by writing to Department A-3, Eutectic Welding Alloys Co., 40 Worth St., New York 13, N. Y. Please ask for the bulletin EW-20—Production Ideas.

Announcing



the POST-WAR FLASH WELDER

These new standard PROGRESSIVE flash welders are not "improved models". They are designed to surpass anything previously built in the way of flexibility, ease of operation, reliability, simplicity of control and ease of maintenance.

Here are a few of their features which spell lower over-all production costs for you:

- Completely self-contained—no accessories needed
- Inclined or flat top (optional)—easy loading—faster output
- Heavy platen designed for interchangeable fixtures
- Simple controls—fewer adjustments—cuts set-up time
- Hydraulic operation—no mechanical linkages to adjust
- Standardized enclosed operating units—"unit-removable" for service
- Standardized dies—quick replaceable
- Rigid one piece steel frame
- Slide rail platen—bearings outside of flash zone.

We will be glad to send you preliminary bulletin #203 giving further details. Please state maximum size of work and materials being welded or to be welded.

IT PAYS TO WELD

PROGRESSIVE Welder Co. 3050 E. OUTER DRIVE • DETROIT 12

RESISTANCE WELDING EQUIPMENT

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this Section

ELECTRODE FOR HIGH-TEMPERATURE CORROSION-RESISTANCE WORK

Chromend 9-M, an alloy electrode giving 8 to 10% chrome and 1.5% moly weld deposit, has been developed by Arcos Corp. to meet the need for an electrode that will give greater strength and greater corrosion resistance combined with high creep resistance for high-temperature corrosion-resistance work.

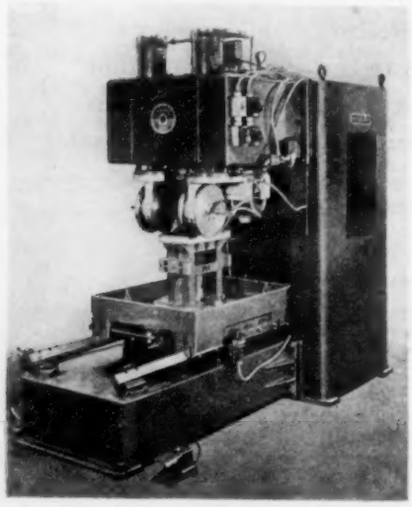
Chromend 9-M bridges the gap between Chromend 5-M, a 4–6% Chrome-Molybdenum electrode and Chromefid 12, a 12% Chrome-Molybdenum Electrode.

Detailed information and samples will be supplied upon request to Arcos Corp., 1515 Locust St., Philadelphia 2, Pa.

SEAM WELDER FOR WELDING TWO OR MORE SEAMS SIMULTANEOUSLY

Duplex seam welders, designed for simultaneous seam welding of two or more parallel seams on one surface, have been announced by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12, Mich. Originally engineered and produced by Progressive for lower cost, rapid fabrication of sheet steel ammunition boxes for the Ordnance Department, these new resistance welding machines offer definite economies for many similar types of fabricating operations.

The machines, available in a wide range of capacities and sizes, are air operated and fully automatic. A duplex head on the machine accommodates either two or four welding wheels. On the model shown in the accompanying photograph, two seam-welding wheels are provided on each of the two welding heads. The outer wheels are of larger diameter to provide clearance for the inner wheels while the outside wheels are used for welding. All wheels are free rotating. They are driven by contact with the moving work under welding pressure.



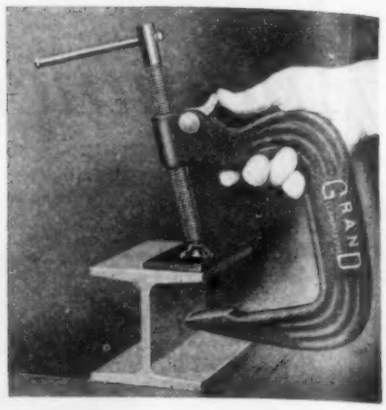
The work itself is carried on a work table mounted on horizontal slide rails. The top of the work-holding fixture is formed by a flat copper plate which provides the lower path for the welding current between the welding wheels. Thus, the platen top becomes the lower electrode for both wheels. Welding wheels, lower electrode, welding transformer, etc., are all water cooled. A deep coolant trough is integral with the moving work table.

"Progressive" Duplex Seam Welders are available with transformer capacities up to 500 kva. to meet users' requirements; a wide range of work table sizes and travels; and many combinations of welding wheel diameters and spacings. Conventional timing and sequence controls are used. Stroke of the head is adjustable. On the model shown in the accompanying photograph, maximum stroke of the head is 7 in.; maximum clearance from work table to welding wheels is 16 in.; and maximum table travel is 25 in. Over-all height of the machine is 87 in.; and it requires a 90-in. by 51-in. floor space.

CLAMPS

Grand Specialties Co., Grand Ave. at Troy, Chicago 22, Ill., announces a new line of Extra Deep Throat Speed Clamps. In addition to the extra deep throats, for which there have been many requests, this new type of "C" clamp, known as the Grand ASL Extra Deep Throat Speed Clamp, incorporates "quick-action" features. It is claimed that the clamp can be positioned instantly by simply pushing down on the ratchet screw (eliminating waste time and motion required to run down the conventional type of clamp screw) and tightening with a turn of the loose-proof handle. The clamp is said to release instantly by merely loosening the handle and pushing with thumb or finger on trigger release pawl which frees the ratchet screw so that the clamp is ready immediately for application to work of any other size or thickness.

This new line of clamps includes three sizes and the manufacturer draws particular attention to the extra deep throats in relation to maximum opening sizes, as follows: $4^3/_4$-in. opening—$4^1/_4$-in. throat; $6^3/_4$-in. opening—$4^3/_4$-in. throat; $8^3/_4$-in.



opening—6-in. throat. Claimed capacity of each size is 3500 lb.

"NON-SPATTER" WELDING FILM

A liquid designed to minimize the adherence of welding spatter to metal and reduce cleaning time has been introduced by The Lincoln Electric Co., Cleveland, Ohio.

This new product which is priced at only a few cents a quart is known as Lincoln "Non-Spatter" Film. The liquid has been thoroughly tested in the field and found to possess the following characteristics:

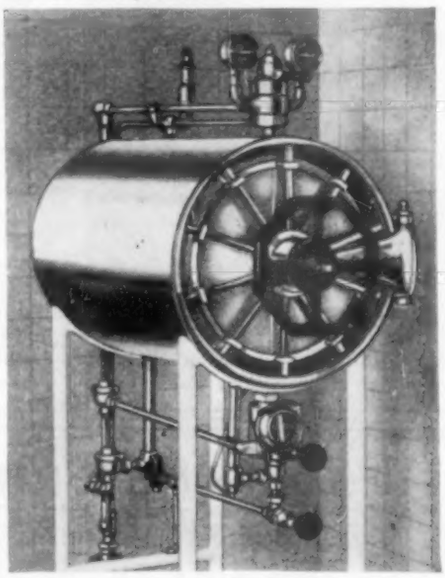
- Welding can proceed after application, whether the film is still wet or dry.
- Film can be sprayed or painted on work.
- Priming coats of paint may be readily applied over the film.
- If it is desired to remove the film before painting, this can be readily accomplished by washing with water.
- One application of film is effective for multiple-pass welding.
- If film is sprayed or painted on parts prior to being normalized, the oxide film and ordinary scale can be removed more easily after heat treating.
- Material will freeze but freezing has no effect on its properties when thawed out.

Lincoln "Non-Spatter" Film is supplied in concentrated form in 5-gal. cans

Welded Truck Wheel Showing Absence of Spatter on Areas Treated with Lincoln "Non-Spatter" Film

Carbon-arc welding an Everdur sterilizer shell at American Sterilizer Company.

Below, the complete unit.



IN THESE DAYS of shortages and fabricating innovations, Anaconda Welding Rods are proving useful in solving production problems, as well as in repair and salvage welding. A typical example is the production welding job illustrated.

For their sterilizer shells, American Sterilizer Company, Erie, Pennsylvania, formerly used Anaconda cold drawn, seamless, red brass shells. Production of large diameter tubes and shells was accelerated to the point where delivery for important hospital equipment could not equal requirements. The American Sterilizer Company are now making shells of welded Everdur* sheet. Anaconda Welding Rods of the same composition are used, and the seams are carbon-arc welded.

For welding copper and nickel or their alloys, steel, malleable and cast iron, there is a suitable Anaconda Welding Rod. For detailed information on these rods, together with practical suggestions relating to their use, write for Publication B-13, "Anaconda Welding Rods." 45112

*Reg. U. S. Pat. Off.

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*

KEEP FAITH WITH YOUR FIGHTERS AND YOURSELF! BUY WAR BONDS

ANACONDA

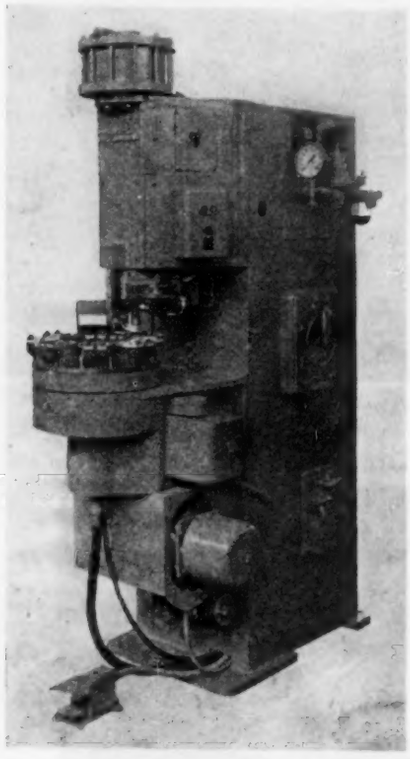
Anaconda Welding Rods

for the convenience of the user. By diluting the concentrated material with three parts of water, 20 gal. of film fluid is obtained.

Either brush or air gun can be used to apply the film to the areas adjacent to the point to be welded and to welding jigs that may be subjected to spatter. After welding, the spatter can be easily removed by wiping or brushing, thus reducing cleaning time to a minimum.

DUAL HEAD, CIRCULAR DIAL FEED PRESS TYPE WELDERS

According to the manufacturers, the last word in high-production welding equipment is embodied in the machine illustrated.



By a unique arrangement of the secondary circuit, this machine welds two assemblies simultaneously with precisely the same amount of current as would be required to weld only one assembly and with even less power demand.

Reference to the illustration shows that indexing of the dial is obtained by use of a Geneva motion, motor driven through a suitable gear arrangement. Correct sequence operation of the welding head is insured by a drum switch of the adjustable fan cam type which only permits welding during the locked intervals of the Geneva.

Two welds are made in series simultaneously and this basic feature of Taylor-Winfield Dial Feed Welders results in several outstanding advantages.

A single air cylinder is connected to two heads through an antifriction bearing equipped equalizer bar which insures identical pressures on the two welding dies. The heads are of the square quill type mounted side by side in common slide. The dies of the two heads are connected to the two pads of the transformer secondary by flexible copper bands. As a result, the inductive loop of the secondary is reduced to a minimum and maximum electrical power factor and efficiency are obtained. Note that troublesome sliding secondary contacts have been completely eliminated. Taylor-Winfield Corp., Warren, Ohio.

BRAZING CARBIDE TIPS TO TOOL SHANKS

Newcomer Products, 155 Gerard St., Latrobe, Pa., has developed a new method of brazing cemented carbide tips to tool shanks which the manufacturer claims will prevent the cracking of the carbide tip, and at the same time permit heavier cuts and longer tool life. This new method, developed after considerable research by William Newcomer, a pioneer in the carbide field, can be satisfactorily applied regardless of the make or grade of carbide.

Carbides, being extremely hard, are low in tensile strength. Therefore, it became necessary to develop a method of brazing the tips to tool shanks which would not leave the tip under a brazing strain. This inherent strain is caused by the steel (or cast iron) shank contracting approximately twice as much as the carbide after the brazing material has frozen. As a result, the strain thus created manifests itself in the forms of cracks developing near and parallel to the braze during grinding or as cracks through the length or width of the tip when subject to the strain and thermal shock of normal cutting.

These properly brazed tools are now being used by large shell manufacturers who are getting 3 to 10 regrinds per tool where formerly as much as 60% of their previous carbide tools broke on the first grind.

The upper half of the accompanying illustration shows a cracked carbide tip in a finishing tool for 8-in. M-106 shell, magnified to emphasize defect, which occurred on first run. The lower half of illustration shows a properly brazed Newcomer tool which, according to experience, permits 3 to 10 regrinds depending upon treatment.

Newcomer Products is prepared to furnish carbide tipped tools in a "milled and brazed" state, or the firm will braze tips and shanks supplied by the customer. Complete details will be furnished by the manufacturer on request.

ACCURATE TEMPERATURE SIGNALING FOR BLACK HEAT RANGES

Critical temperatures of many metals often occur in the black heat range where even a rough approximation of exact temperature is difficult to make. Carbon or carbon-moly steel, for example, suffers a loss of ductility in the so-called "blue-brittle" stage from about 300° to 500° F.

"Burning" of aluminum and magnesium and their alloys begins to take place at about 950° F. before any perceptible

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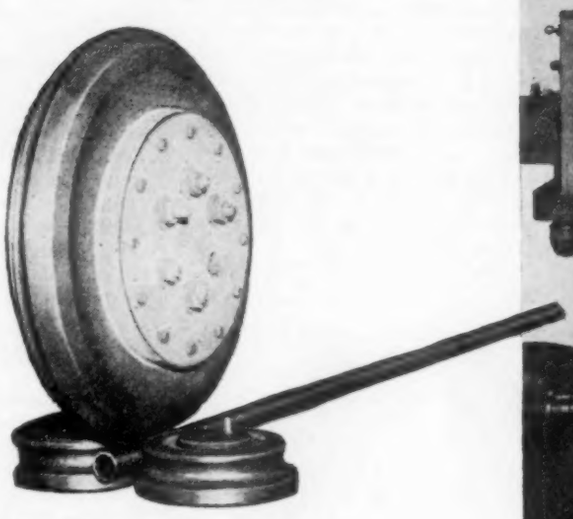
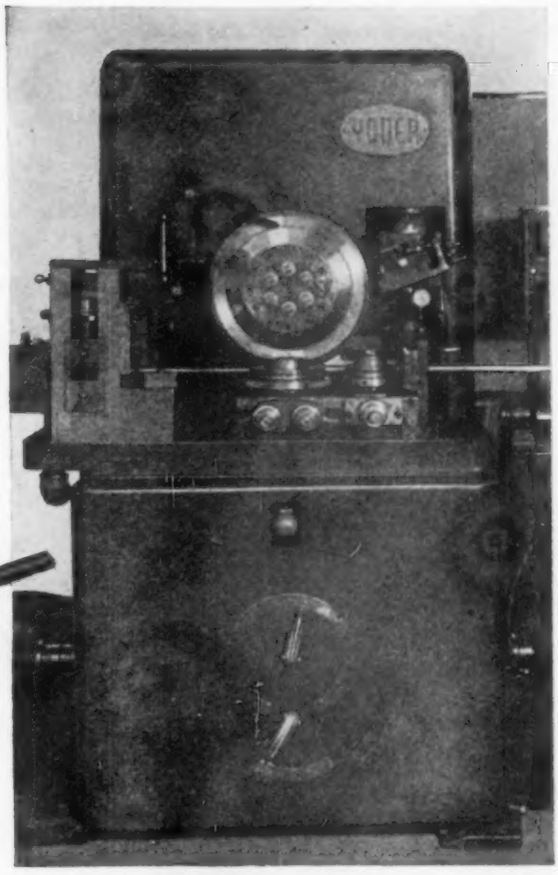
EMPIRE STATE BUILDING, NEW YORK 1, N.Y.

MALLORY
Seam Welding Wheels





Speed Production of Steel Tubing

STEEL tubing from ¼" to 26" in diameter and from 0.015" to 0.75" in wall thickness is seam welded from steel strip in modern tube mills. In the smaller sizes, production speeds of 100 feet per minute are common.

Coils of steel strip are fed into forming rolls and shaped into tubes. As the two edges meet under pressure, they are butt welded into tubing. What appears to be a single large electrode is actually two wheels separated by insulation. These wheels make contact with each side of the seam and act as current carrying electrodes in performing the welding operation.

Made of Mallory 3* Metal, these two seam welding wheels assure high speed production and a minimum of down time for dressing. Welds are sound, clean and strong.

For resistance welding of various metals—mild and alloy steels, stainless steels, aluminum or plated metals; by spot, seam, flash, butt or projection welding—Mallory engineers have developed electrodes that assure faster, better welding at lower cost. Special Mallory electrode alloys such as Mallory 3 Metal, Elkonite* and Elkaloy A* are helping metal fabricators to set new production records.

Write today for your free copy of the Mallory catalog on resistance welding electrodes. Our engineers will gladly help with any specific problem.

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

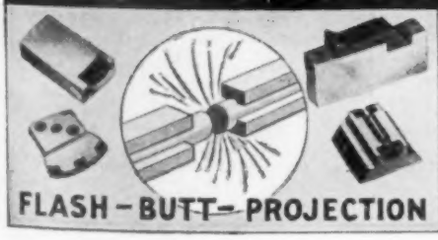
Valuable Information—

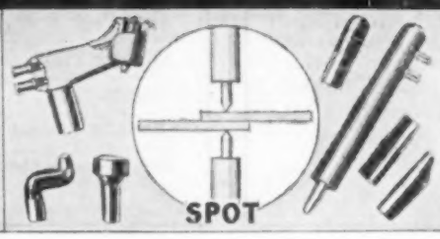
Improved, revised, and expanded, the Mallory Resistance Welding Data Book (3rd Edition) is the most useful manual available on resistance welding methods, machines and materials. Free to those using resistance welding, when requested on company letterhead. Price to students, libraries and educational institutions: $2.50 per copy, postpaid. Board covers, 8½" x 11", 160 pages.

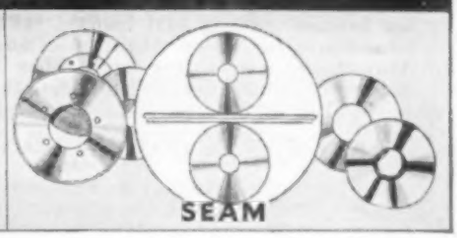
**In the United Kingdom, Made and Sold by Mallory Metallurgical Products, Ltd., London.*

P. R. MALLORY & CO. Inc

MALLORY *Standard Resistance Welding Electrodes*







indication of temperature is given by color.

In flame cutting, too, it is difficult to determine temperatures while the metal is in the black heat range.

Three issues of the technical bulletin "Tempil° Topics" cover some of these problems of temperature control, and give suggested solutions. Ask for No. 1—Flame Cutting; No. 2—Aluminum and Its Alloys; and No. 3—Fabrication in Safe Temperature Ranges. Available free from Tempil° Corp., 132 W. 22nd St., New York City 11.

"INSULATING" WELDING GLOVES

Novel safety device at Graham-Paige Motors Corp., Detroit, is this handy mitt-dryer designed to protect employees welding Alligator amphibian tanks. Perspiration, with its high salt content, is a good conductor of electricity and increases the danger of serious shock to workers handling electrical equipment. To eliminate the hazard, welding gloves are now rapidly dried by slipping them over narrow chimneys protruding from a metal cabinet which contains a heater and fan. Six pairs at a time receive the hot-air treatment.

NEW CHEMICAL METHOD RECLAIMS BURNER TIPS AND FITTINGS

A simple chemical method for reclaiming burner tips and welding torch fittings without manual labor is announced by Turco Products, Inc., of Los Angeles.

Burner tips and fittings used on welding torches and for brazing and burning choke up with tenacious carbon, causing dimensional changes which reduce the efficiency of the equipment. Manual methods of cleaning consume large amounts of time, and rarely is the equipment restored to its original state of efficiency. For lack of an effective method of cleaning, burner tips and fittings have frequently been discarded. To solve this problem, a simple, two-stage chemical process was developed, which makes possible the salvaging of hundreds of these parts.

The Burner Tip at Left Seemed Hopelessly Carbonized and Fouled. After Treatment in Turco L-780 and Turco Brass Dip (right) Carbon and Tarnish Were Completely Removed, and the Burner Tip Restored for Many Additional Hours of Use

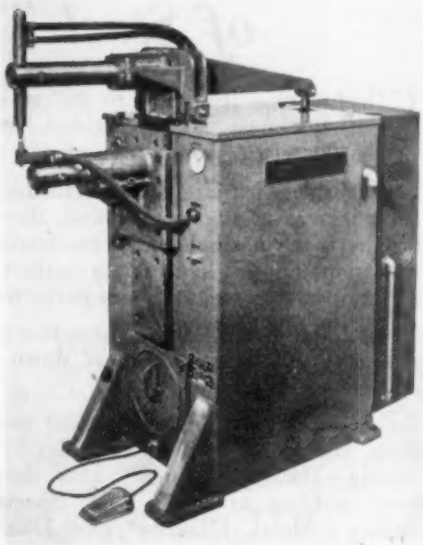
Burner tips and fittings are first soaked in Turco L-780, a liquid material with solvent and penetrating actions, which digests carbon and gum deposits, softening and loosening them so that they are freely rinsed away. The material is noncorrosive to copper and brass. Noninflammable, Turco L-780 mixes readily with water, thereby avoiding the use of costly, inflammable solvents in the rinse. The compound is used at room temperature, in an ordinary steel tank or container, such as is readily available at most plants. An overnight soak is sufficient to loosen and soften all carbon and dirt. At the completion of the soaking period, the parts are rinsed clean in a vigorous air and water spray.

After the Turco L-780 treatment, the parts will be physically clean, but will be more or less heavily oxidized and tarnished because of the high heat to which this equipment is exposed. A brief dip in Turco Brass Dip, a safe detarnishing liquid, completely removes this film, leaving the metal completely clean and bright. Turco Brass Dip is used in a ceramic crock or container. Long-lived and active, a small amount of the material will clean several hundred burner tips and fittings. Turco Brass Dip not only brightens the metal, but passivates the surface, thereby rendering it resistant to corrosion between cleaning periods.

Literature describing the process in detail is available without cost.

PRECISION WELDER

The advantages of starting from scratch in the manufacture of resistance welding equipment are indicated in the Precision rocker arm air-operated spot welder just announced by Precision Welder and Machine Co. of Cincinnati, Ohio. This welder embodies all present adjustment



Buy "Proven Fluxes" with Years of Guaranteed Satisfaction behind them
The Trade-Name is "ANTI-BORAX"

Ask for Them ***Unequalled for Quality***

A Flux for every metal: Cast Iron Welding Flux No. 1; Brazing Flux No. 2; Braz-Cast Flux No. 4 for bronze-welding cast iron; "ABC" Aluminum Flux No. 8 for sheet Aluminum and all alloys of Aluminum; Stainless Steel Flux No. 9; Silver Solder Brazing Flux No. 10; No. 16 Silver Solder Paste Flux.

ANTI-BORAX COMPOUND COMPANY

Fort Wayne, Indiana

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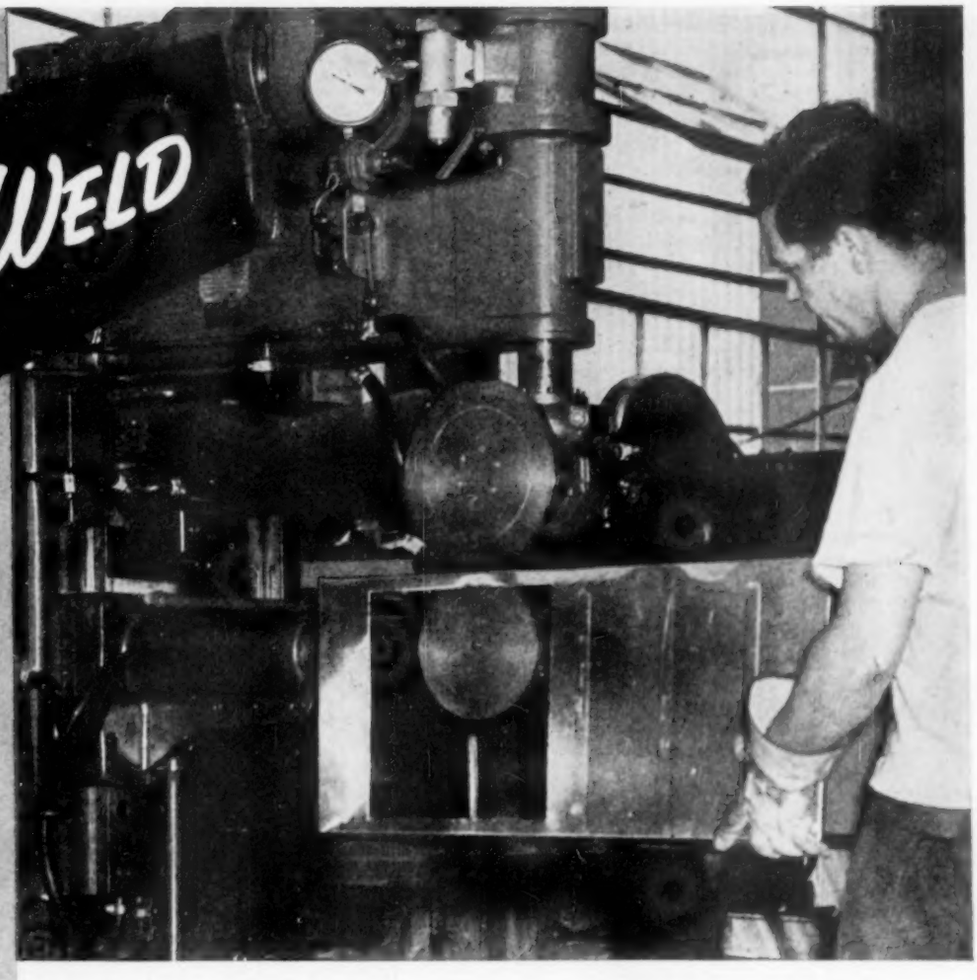
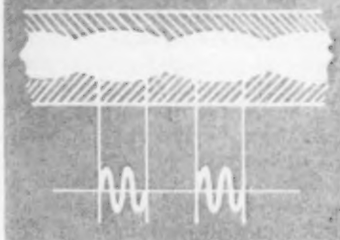
*Inside Preferred	135	120	110	100

*10% Extra for bleed full pages. Color $40 Extra per color added

SEAM WELD

...when it has to be watertight





Schematic cross section diagram of a seam weld. Interrupted current is generally used and produces a succession of overlapping spot welds. Electronic timers control the sequence of a typical setting: 2 cycles weld time and 2 cycles off time. Current values slightly higher than used for single spots are required due to the shunting of the adjacent weld.

FAST Higgins landing craft must use distilled water in the cooling of their power plants. It is essential that the distillation unit be both sturdy and splash-proof.

In fabricating this unit, Higgins Industries, Inc. uses *seam welding*. The Sciaky welder above is speeding the production of distiller cabinets. A single sheet of 24 gauge Monel metal is formed, then welded with a single longitudinal lap joint near the corner. The result is a strong, waterproof joint, produced with speeds up to 78" per minute. No special skill is required of the operator.

We can help you design your product to take advantage of this modern fabricating process. A variety of special wheels, mandrels and jigs can be adapted to your problem. A new booklet describing our 180 KVA series machines, including general information and tooling data is yours for the asking. Write for bulletin 113-A.

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Offices in New York, Washington, Cleveland, Detroit, Los Angeles
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ELECTRIC RESISTANCE WELDING EQUIPMENT

SCIAKY

and functions of other conventional welders, however, simplifications and refinements have been embodied in keeping with the trend of the machine tool industry. The design of the welder has not been influenced by precedents established to meet production requirements of past years, but is designed to take advantage of the latest knowledge gained in the resistance welding field, together with the newest improvements in air-operated machinery.

Among the features are:

1. Unit construction and easy accessibility keeps maintenance to a minimum.
2. Use of air terminal block increases speed of operation to over 200 spots per minute and keeps piping to a minimum. The solenoid air valve can be removed without removing piping or wiring.
3. Maximum vertical adjustment permitting in excess of 2 ft. with a minimum of 6 in. insures peak efficiency with minimum demand.
4. A completely new design of transformer counting clamps the core the full length and provides complete adjustment for accurate and rigid mounting of the transformer.
5. Timer and contactor mounting on hinged rear panel saves the user valuable floor space at the sides of the machine, and provides access to the interior.

ELECTRODE FOR WELDING JET PROPULSION ENGINES

Arcos Corp. announces a new electrode for welding the metals developed for jet propulsion engines.

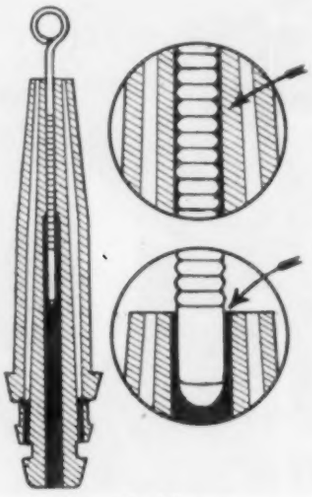
The electrode produces a weld metal that withstands the great temperatures and stresses encountered in jet propulsion engines.

Although the chemistry and physical properties of this new weld metal cannot be revealed publicly, Arcos Corp. is prepared to supply this electrode for those manufacturers engaged in this program. Address Arcos Corp., 1515 Locust St., Philadelphia 2, Pa.

NEW ACETYLENE TORCH TIP CLEANER

Manufacturer: Maitlen & Benson, 1312 Rose Ave., Long Beach 4, Calif.

Features: A better job of acetylene burning, lower labor, maintenance and tip replacement cost with increased production is the record set by the new Wypo Tip Cleaner. The superior efficiency of the Wypo Tip Cleaner is due to its smooth round pilot and its evenly rounded-shoulder stainless steel construction. It is radically different from any cleaner heretofore made. It cleans and polishes the inside of the tip without damaging it—so common with makeshift cleaners that cut, scratch or gouge it. The Wypo Cleaner is long wearing and non rusting. It not only outperforms but outlasts other types of cleaners many time over.



Wypo Tip Cleaner

One shipbuilding company alone, trying the Wypo Cleaner, found it so efficient and practical that they have made it standard equipment for their burners, having purchased over 35,000 Wypo Tip Cleaners. The handy leather case of 12 cleaners fits any size of preheat, high pressure, oxygen and acetylene holes, in the drill sizes of Nos. 75 to 49, inclusive. The case holds the cleaners together protecting them against loss and making them easy to carry in the workman's pocket. Individual larger sizes are made to fit the larger burning tips.

ACP ELECTRODES

For speedy and economical welding in all positions and with a.-c. and d.-c. reverse polarity, the new ACP electrode available in seven diameters from $^5/_{16}$ to $^3/_{32}$ in. is announced by the Westinghouse Electric Corp.

The new heavily coated electrode, recommended for high-quality welds on work which is not easily positioned, forms a light, porous slag which is easily removed from each pass by light brushing. Because of high tensile strength and ductility of welds made with ACP, this rod is especially suited for heavy plate fabrication, shipyard, pressure piping, pressure vessels and general structural steel work.

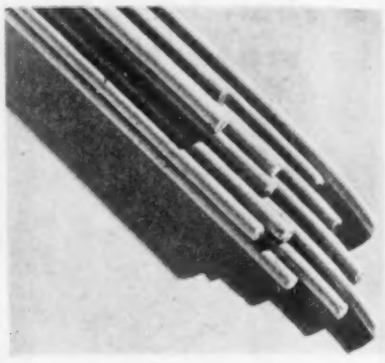


Fig. 1—New ACP Westinghouse Electrodes for A.-C. and D.-C Welding

Easy to handle on vertical and overhead work, ACP produces excellent results in making horizontal fillet welds and lap joints on all low and medium carbon steels, as well as low-alloy and cast steels. It meets Navy specifications as well as various association code requirements.

Further information on the ACP electrode may be secured from P. O. Box 868, Westinghouse Electric Corp., Pittsburgh 30, Pa.

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For All Types of Resistance Welding. . . . Accurate—Fool Proof—Simple—Low Priced. . . .
War Contracts Must Be Qualified. Post War Welding will Surely be Held to Equal Standards.

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investigate EUTECTIC RODS AND FLUXES

*Low Temperature** Welding

For production work, an ever increasing number of leading manufacturers are now using EUTECTIC Rods and Fluxes in place of fusion welding, brazing and silver soldering, because the EUTECTIC Low Temperature* Process affords them new economies and additional advantages over conventional welding methods. Not only are many of the most difficult problems solved through the application of EUTECTIC Rods and Fluxes but ordinary welding jobs are performed at lower cost by means of this revolutionary process.

In the solution of numerous welding problems involving high strength, freedom from distortion, warping and minimum after-machining, the record of EUTECTIC achievements is constant proof of the superiority of EUTECTIC Low Temperature* Welding Rods and Fluxes.

EUTECTIC RODS AND FLUXES FOR EVERY METAL JOINING JOB

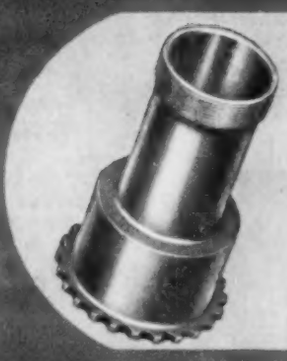
By means of 48 specially developed Rods and Fluxes the many advantages of EUTECTIC Low Temperature* Welding can be employed to join all metals. Every standard method of heating such as Gas — Arc — Induction and Furnace can be used since EUTECTIC Low Temperature* Rods and Fluxes are supplied in rod, wire, strip and powder form to meet all requirements.

If you have tough metal joining problems or are planning new production, NOW is the time to investigate EUTECTIC Low Temperature* Rods and Fluxes by calling in your local EUTECTIC Field Engineer who will gladly help you. In the meantime, why not order the all-round selection of 9 important EutecRods for your current work and experimental jobs. Mail the coupon or write on your company letterhead.

EUTECTIC solves tough welding problems and makes routine jobs easier. Try it today!

*Reg. Trademark U. S. Pat. Office

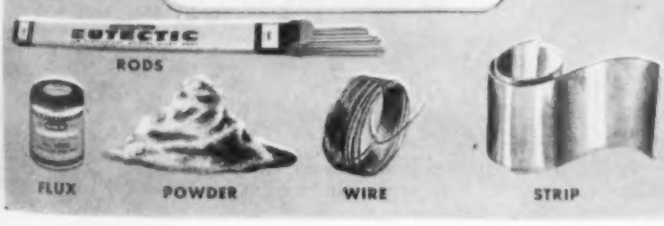
Bronze castings welded with EutecTrode 28. This is the first electrode developed that can successfully weld copper, brass and bronze with an AC-DC metallic arc. Completely machinable, perfect color match; high tensile strength.



Steel sprocket gear welded with EutecRod 16. Carloads of steel were saved by simplifying the design of this machine part. Separate components were welded together with high tensile EutecRod 16.

Aluminum tubing washer and four aluminum screws assembled with EutecRod 190. Note that on thin aluminum sections, welds made with this alloy minimize distortion. This costly forging was produced by welding together aluminum components—a testimonial to the speed and qualities of EutecRod 190.

Castolin Eutectic



EUTECTIC WELDING ALLOYS COMPANY

ORIGINATORS OF EUTECTIC LOW TEMPERATURE WELDING

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Please send me complete facts about EUTECTIC Rods and Fluxes and information on how to purchase a selection of the 9 most important EutecRods for every day use.

Dept. JN1

Name.....

Company.....

Address.....

NEW REFERENCE CHART ON ALLOY WELDING

Arcos Corporation has just announced a completely new and simplified reference chart on high and low alloy welding electrodes. The data, which is grouped for quick, easy use, includes weld metal chemical analyses; information on corrosion resistance, on heat resistance, and on weld metal surfacing. It also includes welding currents and voltages and stub end color table. A copy will be sent upon request to Arcos Corporation, 1515 Locust Street, Philadelphia, 2, Pa.

CUTTING AID

Flame-cutting vertical and overhead, as well as horizontal surfaces, is said to be greatly facilitated by the new B & W Magnetic Straight Edges, according to the manufacturer, The B & W Co., 7610 S. Figueroa St., Los Angeles 13, Calif.

An 18-lb. pull holds the B & W Magnetic Straight Edge firmly to the work whether the plate is rusted, oily or painted. The Alnico magnets, which are not affected by electricity, are said to last for years.

Uniformly clean and accurate cuts are assured because the torch tip is held at the correct distance from the work. The straight edges are easily adjustable to any bevel angle. Bevels are cut in one operation.

Made of specially heat-treated aluminum alloy, rigid as well as light in weight, B & W Magnetic Straight edges will not warp from heat and are resistant to corrosion.

Three models are offered in lengths from 18 to 36 in.

NEW CARBON PILE CONTACTOR-CONTROLLER

Details of design and construction of the unique contactor-controller which has made possible the introduction of successful resistance welding machines operated from storage batteries as the direct power source, have now been released by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12, Mich. These contactors make possible the rapid interruption—without arcing—of welding currents ranging up to tens of thousands of amperes. With this equipment it is now possible to weld even such materials as aluminum—requiring high current values—in localities where power supply is quite limited.

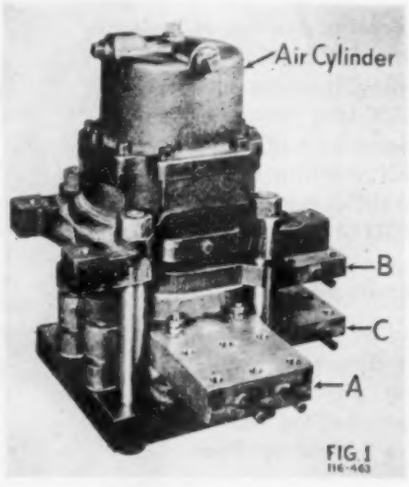


Fig. 1

The carbon pile contactor used on the "Progressive" battery-powered resistance welding machine is a rugged, heavy-duty assembly capable of making and breaking extremely heavy currents continuously. Units of this design in operation at the present time interrupt upward of even 30,000 amp. on regular high-production jobs.

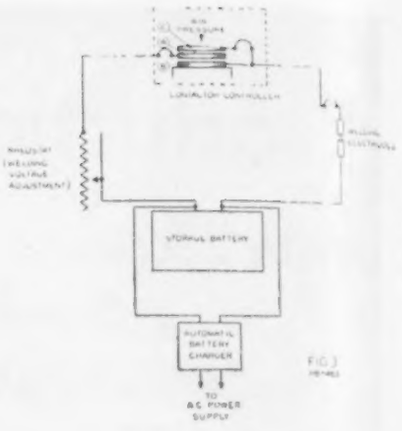


Fig. 3

This sketch illustrates the two paths for the flow of welding current provided by the four contacting surfaces. Current flows through the contactor, thus doubling the capacity of the unit. One path is through the bottom contact to the central one, that is, from *B* to *A*. The other path is through the top contact to the central plate, or from *C* to *A*.

Design and operation of the contactor is based on utilization by Progressive of a well-known but hitherto relatively neglected electrical principle: the carbon pile rheostat. Such rheostats have the ability to control the current flowing through a circuit merely by varying the pressure applied to a stack of carbon disks. Maximum current flows when the carbon is highly compressed. The current decreases proportionately as the pressure is released.

Instead of having many small disks in series, however, the Progressive contactor-controller is designed so that the current passes from two large carbon disks into a third one which is located centrally between the other two. The carbon pile contactor itself (see Fig. 1) is a rugged, heavy duty assembly capable of making and

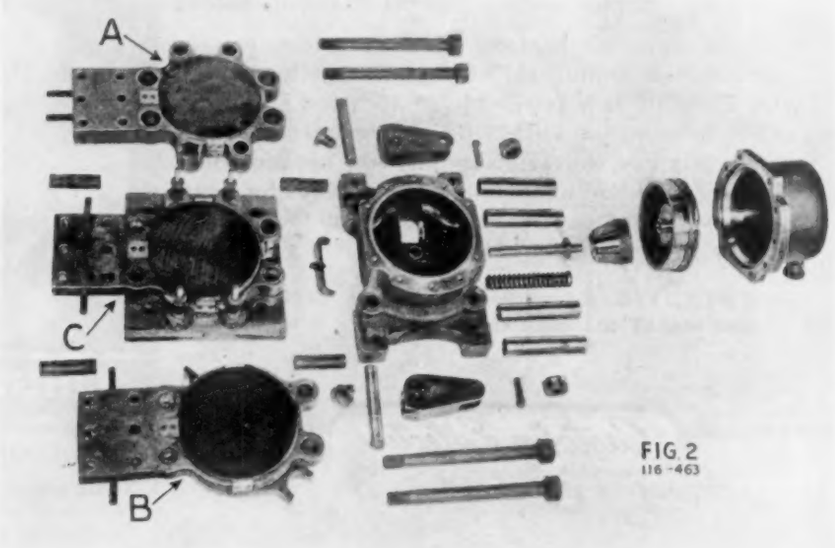
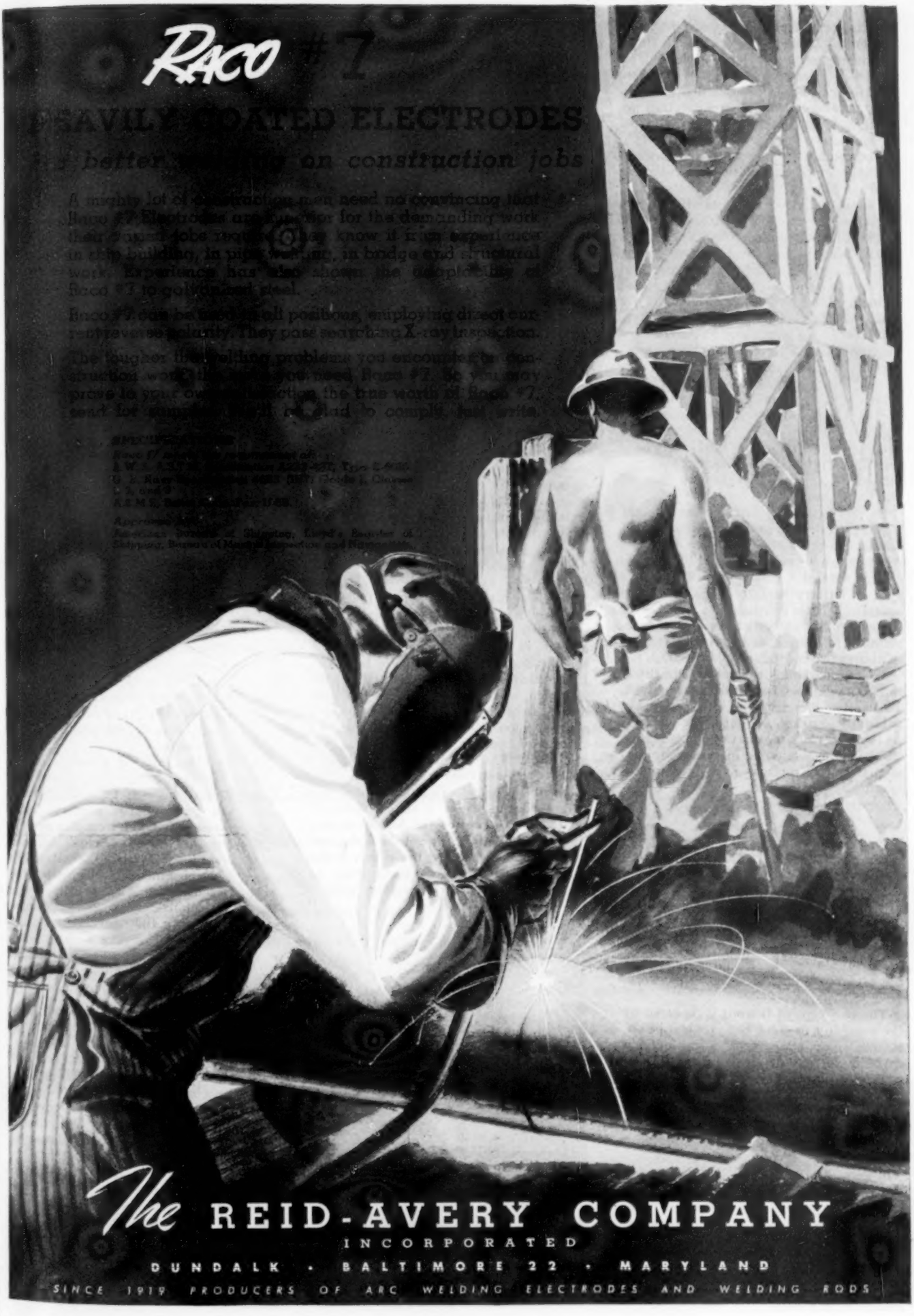


Fig. 2

The contactor proper is made up of the centrally located contact plate *A*, having a carbon disk surface top and bottom. It faces similar carbon disks mounted on the upper and lower contact plates marked *B* and *C*.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SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

breaking extremely heavy currents continuously. Units in operation at the present time interrupt upward of even 30,000 amp. on regular high production jobs. No sparking can be seen between the carbon disks as the current is broken—only an occasional glow from a speck of heated carbon dust.

The contactor consists of the centrally located contact plate (*A* in Fig. 2) having a carbon disk surface top and bottom, facing similar carbon disks mounted on the upper and lower contact plates (*B* and *C* in Fig. 2). When assembled, the contact surfaces are barely separated by only a few thousandths of an inch. When the contactor is to be closed, air is admitted to the cylinder above the contact assembly by means of an electric solenoid air valve. This operates a piston and forces the contacting carbon disks together under a pressure of several thousand pounds.

The four contacting surfaces (see sketch, Fig. 3) actually provide two paths for the flow of welding current through the contactor, thus doubling the capacity of the unit. One is through the bottom contact to the central plate (from *B* to *A*), the other through the top contact to the central plate (from *C* to *A*).

As the contacting surfaces are brought together, they offer at first considerable resistance to the flow of the current. This resistance, however, drops rapidly as pressure is applied. Under the full pressure used in battery welding machines, there actually is little resistance to the flow of current. The carbon disks are so compounded, of course, as to produce the desired pressure-resistance relationship.

When the welding current is to be interrupted, the air pressure is simply removed. This action allows springs in the assembly to rapidly separate the contacting surfaces. As the pressure between the plates is thus released, the resistance increases rapidly, so that, as the surfaces actually separate, practically no current remains to be interrupted.

NEW THERMIT

Development of a special type of thermit, known as "Thermicast," for producing steel castings, has been announced by the Metal and Thermit Corp., New York, N. Y.

The new type of thermit is reported by the company to solve the problem of obtaining sound, clean steel castings quickly and simply, irrespective of size and intricacy of shape, when regular steel melting facilities are unavailable. Thermicast is especially designed for the production of steel castings and is not to be associated with welding for which it is not suitable.

The new casting material utilizes the well-known thermit reaction, requiring neither fuel nor electric power, the reaction being carried out in a specially designed conical-shaped crucible of sheet steel lined with refactory material. Most of the equipment required to produce the castings can be improvised, and little experience to produce steel castings by the process is necessary.

Thermicast is available in 41-lb. bags, each of which produces approximately 25 lb. of steel. The Thermicast steel, as cast, has the following average physical properties: yield point, psi., 39,250; tensile strength, psi., 70,200; per cent elongation in 2 in., 30.1, and per cent reduction in area, 51.2.

PORTABLE HARDNESS TESTING HAMMER

An instrument that makes practical the taking of a hardness test right where the material is, in the shop, yard, on the truck, car, anywhere it may be, instead of taking a specimen to a testing machine, is announced by Steel City Testing Laboratory, 8843 Livernois, Detroit 4, Mich., and it is identified as a Portable Hardness Testing Hammer Type "P." While the usual method of checking for hardness is by means of costly testing machinery, using especially prepared test pieces; in many instances it isn't at all necessary to obtain a scientifically accurate test of the material, but it is sufficient to know the hardness in regard to workability. With this self-acting Hammer, it can be done quickly, employing any unskilled labor. Repeated tests can be made without readjusting the hammer. If material of a certain degree of hardness is to be selected, it is only necessary to see whether the diameter of the impression made corresponds to the desired degree of hardness. If the impression is smaller or larger, the specimen is either to hard or too soft, which can be checked with microscope and chart supplied. The hammer consists of a cylindrical housing and easy moving piston; the housing is closed on one end with an inside thread cover, and on the other end with an open bushing. Between the cover and the piston, a strong spring is located which presses the piston against the bushing. The tension of the spring can be adjusted by turning the cover, if the hammer is to be set a certain power of stroke. The piston is coupled with a striking piston, which projects through the bore of the bushing guided by an airtight fitting ring in the cylinder and carrying a steel ball on the end.

Resting the hammer with the ball against the material to be tested and pressing on the operating end, the striking piston and the piston in the housing moves inward and presses against the spring between the piston and the cover. At a certain point, in this movement, the coupling between the piston and the striking bolt is released, so that the piston, under pressure of the spring, moves against the inner end of the striking bolt and the ball striking against the material to be tested. After the hammer is released, the striking bolt or piston is brought back to its former position by a spring in the cylinder. The cushion of compressed air before guiding ring causes a slow backward movement of the ball, and prevents spoiling the impression made. Steel City Testing Laboratory, 9843 Livernois Ave., Detroit 4, Mich.

SURFACING ELECTRODES

The Sight Feed Generator Co. of Richmond, Inc., announce a new line of Surfacing Electrodes. These electrodes will be known under the trade name "Rexaloy." They have the following properties and characteristics:

1. Made in sizes $^1/_8$, $^5/_{32}$, $^3/_{16}$ and $^1/_4$ in.
2. Operate equally well on either a.-c. or d.-c. machines, in all positions.
3. Are not affected by moisture to the extent that they are not usable, but, after drying, will perform as formerly.
4. Deposits can be forged and heat treated.
5. The coating is metallic, and becomes a part of the overlay, which means freedom from slag or scale.
6. Deposits have a Brinell hardness rating of 300 to 687, depending on the base metal on which deposited.
7. Designed on the principle that toughness is a more desirable property than hardness, Rexaloy electrodes will not become brittle after application, but will retain, within a few points, their original hardness throughout their use.

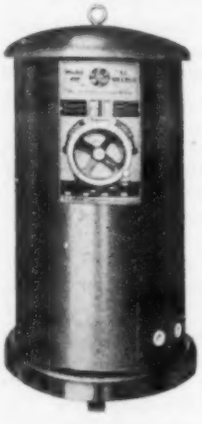
Rexaloy Electrodes are unique in their field, having a coating composed of chromium, nickel, copper, vanadium, manganese and other metals, the amounts of which vary with the type of rod. These blend with the core rod during the welding, forming a dense, slag-free alloy overlay. This principle replaces many desirable elements which are lost, in most electrodes, while passing through the arc.

These electrodes, as an overlay or inlay on a machinery part, prolong the life and increase the efficiency of the part involved. Not only is the worn-away metal of used parts replaced, but loss of metal from the surface of a new part may be minimized by application of a thin layer of a hard alloy, prolonging the life of the surface so protected.

This Girl Is Wrapping Up a *New* PRODUCTION TOOL

In 1917, A. O. Smith developed a method of coating electrodes with paper, which shielded the welding arc and produced welds of materially improved ductility and tensile strength—a revolutionary advance in the relatively primitive art of welding.

Now in 1945, continuous welding research in A. O. Smith laboratories and plants makes possible the fabrication of 28,000-pound stern frames for cargo ships by the electric arc welding method—a process involving standard SMITHway electrodes and a mastery of modern welding preparation and techniques.



Soon . . . a Complete Line of SMITHway A. C. WELDERS

Ready for delivery soon, the expanded line of A. C. Welders includes three new models of 150- 200- and 250-ampere capacity, in addition to the HEAVY DUTY MODELS of 300- 400- and 500-ampere capacity. Write for complete specifications and prices.

The Proof Is in Production

Welding research never ends at A. O. Smith. It goes on in the laboratories. It goes on in actual daily production. Every day more than 320,000 SMITHway electrodes are used in A. O. Smith plants on parts and products ranging from the smallest and simplest to the largest and most complex. Millions are used in the plants of other manufacturers. For detailed specifications on SMITHway Certified electrodes and their application to specific welding jobs, send for the SMITHway Welding Guide.

Mild Steel . . . High Tensile . . . Stainless Steel
WELDING ELECTRODES
made by welders . . . for welders

SMITHway Certified WELDING ELECTRODES

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NEW YORK 17 • PITTSBURGH 19 • CHICAGO 4 • TULSA 3
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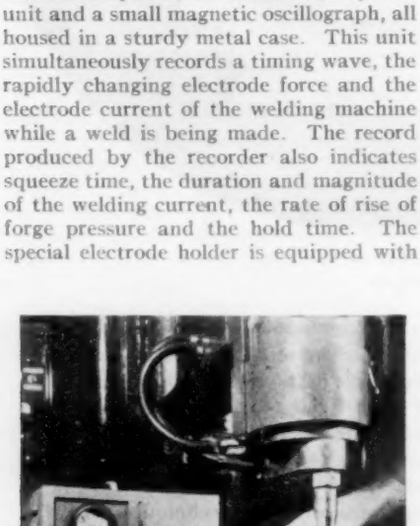
CURRENT-FORCE RECORDER

A new current-force recorder for recording current and force in resistance welding machine electrodes has been announced by the Special Products Division of the General Electric Co. Desirable for use in welding research and for the periodic checking of welding machine performance, the new recorder is specially designed to be helpful to users of energy-storage type welding machines for determining when forge pressure is applied to the work with respect to the discharge of welding current. In addition, the recorder permits resistance welding machine users to comply with Navy Specifications, Navaer PW-6A, Bureau of Aeronautics, Specifications for the Spot Welding of Aluminum Alloy, for Class A Spot Welding.

Compact, portable and easy to use, the recorder consists of an amplifier-oscillograph unit and a special electrode holder. The amplifier-oscillograph unit, which operates from a 115-v., single-phase, 60-cycle power source, is composed of a single-channel amplifier, an oscillator, a power unit and a small magnetic oscillograph, all housed in a sturdy metal case. This unit simultaneously records a timing wave, the rapidly changing electrode force and the electrode current of the welding machine while a weld is being made. The record produced by the recorder also indicates squeeze time, the duration and magnitude of the welding current, the rate of rise of forge pressure and the hold time. The special electrode holder is equipped with



Close-Up View of New Current-Force Recorder in Operation

strain gages for measuring compressive strain, which is a measure of the force in the electrode, and built-in shunt for diverting from the electrode a proportional amount of current, which is used to operate an oscillograph galvanometer.

In operation, a 5000-cycle voltage from the oscillator is applied to two points on the strain gage bridge circuit, and the output from the two opposite points is a measure of the force on the electrode. The output of the bridge is fed into the amplifier, which amplifies the modulated carrier and rectifies and filters the amplified output. The output is then fed to the oscillograph, where the record is made. The welding current and a 60-cycle timing wave are recorded simultaneously on the $3^1/_2$-in. paper record.

TAPERED TUBE USED IN REDESIGN

Recent experience in redesign of a munitions item demonstrates how advantage can frequently be taken of available shapes and how the combination of available shapes with small stampings often turns out to be the best solution for the production problem. Figure 1 shows schematically the ingenious change in design which made it possible to dispense with a large amount of machine work, with a consequent improvement in production rate. The part shown at *A* was originally designed as a hollow forging which required a large amount of machining to reduce the wall thickness to the specified dimension. In order to speed up production and lower the cost, a study was made of the possibility of fabricating it by resistance welding. It would be quite natural to consider first the possibility of sectioning the piece longitudinally and flash welding two

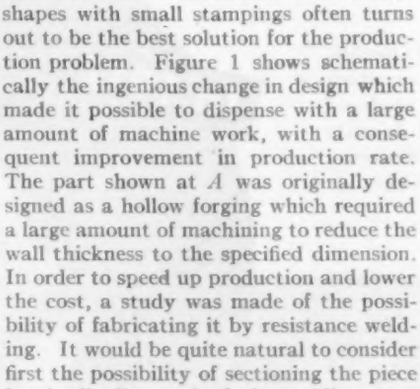


Fig. 1

stamped sections together. This, however, would have involved some difficult problems of die construction for both the stamping operations and the welder. A better method consisted of flash welding two pieces of the general shape shown in *B* and *C*. Part *B* was easily made by taper swaging the required lengths of seamless steel tubing of the correct outside diameter and wall thickness. At the small end of the taper, there is provided a straight tube section, slightly greater in length than the amount of material that would be lost in the flashing and push-up. Part *C* was produced as a stamping from material of the same wall thickness as the tube. This part also has a straight tube section corresponding to that of part *B*, to allow for flashing and push-up. In other words, the two parts were identical in section at the areas where they were to be joined, and therefore presented satisfactory condition for flash welding. The assembly reproduced the shape and dimensions of the original part as shown at *D*. The removal of the flash after welding is only a minor punch press operation compared to the amount of machine work necessary when this part was made from a forging.

ELECTRONICS TRAINING COURSE

A new Industrial Electronics talking slide film training course which offers a thoroughly practical quickly grasped understanding of the subject of industrial electronics, has been announced by the General Electric Co. Carefully organized for presentation in twelve sessions, the new course is expected to have wide use throughout industry wherever electronic equipment is applied or a knowledge of it is required. A large number of industrial and power companies, especially, are expected to find the course highly desirable for effectively presenting to their personnel the fundamentals and applications of industrial electronics.

BRAZING BY RADIANT HEAT

Ann Marks, of the Research Laboratories of the Westinghouse Electric Corp., Pittsburgh, Pa., is shown brazing copper parts in a "hydrogen bottle" by radiation from an incandescent filament. The 2000° C. (3632° F.) attained by the filament heats the copper parts to about 900° C. (1652° F.).

PRODUCTION AND USES OF OXYGEN

A new 24-page, two-color booklet, "Oxygen—Indispensable Servant of Industry," profusely illustrated and fully telling the interesting story about oxygen —how it is made and how it is used in industry—has been published by Air Reduction.

Photographs and text tell how 99.5% pure oxygen is guaranteed users and why this higher oxygen purity assures greater economy and maximum end-use efficiency of the product.

Other explanatory sections describe the different types of "packages" for varying oxygen volume requirements, operating conditions, and internal plant gas distribution methods. Also treated is Airco's Applied Engineering Service for helpful technical and on-the-job assistance. Descriptions of hand and mechanical welding, flame hardening, flame cleaning, underwater cutting, hand and machine gas cutting and other flame processes developed or perfected in Airco's Research Laboratories are included along with photos of apparatus, accessories and supplies and other technical literature.

Copies of the booklet, No. ADG-2014, are available on request from Air Reduction Sales Company, 60 East 42nd Street, New York 17, N. Y., or any local Airco office.

AIRCO TRANSFORMER WELDER

A new 200-amp. Wilson "Bumblebee" transformer welder to meet the need for a high-quality a.-c. machine of medium capacity, incorporating the latest features for economy in power consumption and high-speed, quality welding, has been announced by Air Reduction.

Built-in capacitators make possible power economies up to 35%, reduce power bills and power input and relieve overloaded transmission and plant feeder lines, making room for additional equipment. The unit is also equipped with a disconnect switch.

Self-contained, the new 200 "Bumblebee" has two ranges of current, the low from 30 to 110 amp. and the high from 90 to 275 amp. Continuous stepless current control is provided throughout each current range by simply turning the crank on the top of the machine. A full-view scale makes current settings easy to read at all times.

The machine is entirely self-contained and is studily constructed for dependable, economical service. All windings are covered with the latest spun-glass fiber, heat-resistant Class B noninflammable insulation.

Copies of an illustrated leaflet, giving dimensions, operating data, electrical characteristics, graphs showing volts and efficiency and power factors percentages, and other data, are available on request from Air Reduction Sales Co., 60 East 42nd St., New York 17, N. Y., or any local Airco office.

FORGING PRESSURE SPOT WELDING

The advantage of forging pressure is provided in a new 150-kva. projection welder, announced by Sciaky Bros., Chicago, Ill. The pressure sequence consists of an initial low pressure during the flow of welding current. This is sufficient to establish good contact without burning off the upper side of the projections. The pressure is also low enough to prevent a crushing of the projections which would reduce the heating efficiency of the welding current.

A forging pressure of higher value follows immediately after the passage of welding current. This quick follow-up of high electrode pressure reduces brittleness, sheet separation, and assures uniform welds with a minimum supply of power.

The addition of electrode holders easily converts the machine to a spot welder. A retraction stroke is provided which will permit a short $1/2$-in. working stroke. The machine is a self-contained unit, with electronic controls mounted in a hinged cabinet, convenient to the operator.

The welder, type PMCO1-9, has a capacity of 6 projections on 0.080-in. mild steel. As a spot welder: from two thicknesses of 0.032 to 0.187 in. Throat depth is 18 in. with maximum working space between arms of 21 in. Maximum pressure is 2600 lb. for 90 psi. line.

P&H INTRODUCES NEW ELECTRODE FOR WELDING CAST IRON

"Harcast," an all-position mild steel electrode for welding and repairing cast iron is the latest development of the Harnischfeger Corp., builders of P&H welding equipment. Entirely new, completely different in its operating characteristics, P&H "Harcast" represents years of research and experimentation. It fuses well with either mild or medium carbon steel, thus making it ideally suited for joining cast iron with other types of steel. With a yield point of 50,000 psi., the deposited metal has an ultimate tensile strength of 60,000 lb., roughly double that of a good grade of cast iron.

Usable with either a.-c. or d.-c. machines (straight or reverse polarity on d.-c.), "Harcast" works well at low amperage, thus minimizing the dilution effect at the fusion zone and permitting a higher quality of machining. Reverse polarity on d.-c. current produces a smooth bead with deep penetration. On d.-c. straight polarity, penetration is less, higher beads are built, and there is less spread in the fusion zone. In either case—as with a.-c. current—"Harcast" assures a sound, deep weld for any good grade of cast iron. For full particulars on "Harcast" electrodes, write Harnischfeger Corp., Welding Div., Milwaukee 14, Wis.

BATTELLE RESEARCHES

A 72-page catalog of the publications and patents which have resulted from 15 years of fundamental and applied Battelle research has just been published by Battelle Memorial Institute, Columbus, Ohio.

Founded to advance education, science and industry through research and through the dissemination of technological information, Battelle has published widely in the nation's technical and scientific journals. The new catalog lists more than 800 such journal contributions, books and patents between the years 1929–44, inclusive.

The catalog includes subjects in the fields of organic chemistry, electrochemistry, chemical engineering, graphic arts, welding technology, applied mechanics, mineral dressing, industrial physics, ceramics, fuels and metallurgy.

SUSTAINING MEMBERS

Farwell Metal Fabricating Division, Farwell, Ozmun, Kirk & Co., St. Paul 1, Minn. A modern, completely equipped plant—serving industrials, food, chemical, process and allied industries, doing custom work in stainless steel, Monel metal, herculoy, mild steel and miscellaneous alloys. Fabricating process equipment, tanks, pipe and fittings, entirely to customers' specifications. Also operate a tool and stamping plant in connection with welding sheet, plate and structural work. Specializing in redesign from castings to weldments on machine bases, parts and complete units.

R. K. Tyra Company, Wyoming, Minn. Sheet metal and structural steel, plate cutting and forming, press work, metal stampings, wood work, galvanizing, welding and cutting. Now making tent hardware, aircraft parts, farm machine parts and platers equipment. When restrictions are lifted, will again make all welded sheet metal boats, builders hardware trailers and structural steel work.

Employment Service Bulletin

POSITIONS VACANT

V-168. Welding Research Engineers—Familiar with arc or gas welding, gas cutting and having background of production or research experience in the welding field. Excellent postwar opportunities in a modern research laboratory for men genuinely interested in welding. Write details of education, experience and salary. New York area.

V-169. Design, Development and Research Engineers. Mechanical or Electrical for work in one of the largest Resistance Welder Manufacturers. Salary open. Location, eastern Ohio. Our employees notified of this ad. Reply giving qualifications.

V-170. Transformer Consultant and also a Technician on small portable Electric Welders. Excellent postwar opportunity.

V-171. We are distributors of electrodes and welding products and are desirous of obtaining the services of a man versed in this line to assume sales control for these items. Location Cincinnati.

SERVICES AVAILABLE

A-501. Mechanical Engineer, 2 degrees, 12 years' experience in thermal joining processes, welding design of structures, pressure vessels, piping; welded production, also all phases of Resistance steel and alloys, training in physical metallurgy, strain studies, X-ray diffraction, experience as welding consultant and instructor; seeks responsible position in development, research, design, etc. Also sales position considered.

SECTION ACTIVITIES

The Editor regretfully announces that for the first time in its history the Journal will not publish Section Activities and New Members. Paper restrictions has made this step necessary. This feature will be resumed at the earliest opportunity.

PAPERS SCHEDULED FOR 1945 ANNUAL MEETING, AMERICAN WELDING SOCIETY

EDITORIAL NOTE.—The Annual Meeting papers will be presented to the membership through publication only. Oral presentation will be available only through local Section meetings. In order to provide the membership at large with an opportunity for discussion of these papers, a convention by mail will be arranged. These papers will be published as rapidly as possible in current issues of THE WELDING JOURNAL starting with this issue. In each case an Annual Meeting paper will be available for discussion by the membership at large, up to and including, the 10th of the month following its appearance in THE WELDING JOURNAL. Thus, Annual Meeting papers appearing in this issue will be open for discussion until September 10th. At that time all discussions presented will be sent to the author for closing remarks and the discussion eventually printed in the earliest issue, which in the case of articles appearing in the August issue, will probably be the October number.

AIRCRAFT

Effect of Recent Research on the Weldability and Control of the Production of Steel Aircraft Tubing
by A. J. WILLIAMSON, Chief Metallurgist, Summerill Tubing Co.

Resistance Welding on Stainless Steel Aircraft Motors and Accessories
by FRANK G. HARKINS, Resistance Welding Engr., Solar Aircraft Co.

The Application of Pressure Welding to the Manufacture of Aircraft Landing Gear
by E. R. PROCTOR, Menasco Manufacturing Co.

Heliarc Welding as Applied in the Aircraft Industry
by T. E. PIPER, Chief Process Engr., Northrop Aircraft, Inc.

BRAZING

Impact Strength of Silver Alloy Brazed Joints in Steel
by HOWARD A. SMITH, Met. Engr., Beech Aircraft Corp.

Metal Flow and Fillet Formation in Brazing Aluminum
by DR. M. A. MILLER, Aluminum Research Labs.

Brazing with Oxy-Fuel Gas
by A. N. KUGLER, Air Reduction Sales Co.

DESIGN

Welded Design as Applied to Light Weight Ordnance Structures
by H. A. OLDENKAMP, Project Engr., Warner & Swasey Co.

GAS CUTTING

Recent Developments in Heavy Cutting
by R. S. BABCOCK, Development Dept., The Linde Air Products Co.

Special Oxyacetylene Machine Cutting Applications
by R. F. HELMKAMP, Machine Cutting Spec., Air Reduction

Electric Eye Tracing in Machine Cutting
by WALTER BERGEROW, In Charge of Light Mechanical Section, Air Reduction

Machine Gas Cutting in the Steel Warehouse
by LEONARD J. QUETSCH, Vice-Pres., A. M. Castle & Co.

Machine Gas Cutting
by R. M. DENNIS, Asst. to President, By-Products Steel Corp.

HARD SURFACING AND FLAME HARDENING

Building Up Worn Surfaces by Submerged Melt Welding
by J. M. KEIR, The Linde Air Products Co.

Modern Hard-Facing Methods
by A. R. LYTLE, Union Carbide & Carbon Research Labs.

MAINTENANCE AND JOB SHOP WELDING

Work of the Mobile Ordnance Repair Shops
by Representative of the United States Army, Ordnance Department, Office of Chief of Ordnance

Welding on the Farm
by R. W. GREGORY, U. S. Office of Education, Food Production War Training

Maintenance Welding in Foundry
by RUSSELL R. FITCH, General Foreman, Aluminum Company of America

Railroad Welding-Cutting & Flame Hardening Operations
by J. W. KENEFIC, Supt. Railroad Service, Air Reduction

METALLURGICAL

Metallurgy as Applied to Welding
by R. B. LINCOLN, Director NWTB, Pittsburgh Testing Lab.

Some Observations Concerning Underbead Cracking
J. O. MACK and J. A. REINBOLT, Naval Res. Lab.

Welding 3½% Ni-0.45C Steel
by BELA RONAY, U. S. Naval Eng. Expt. Station

MISCELLANEOUS

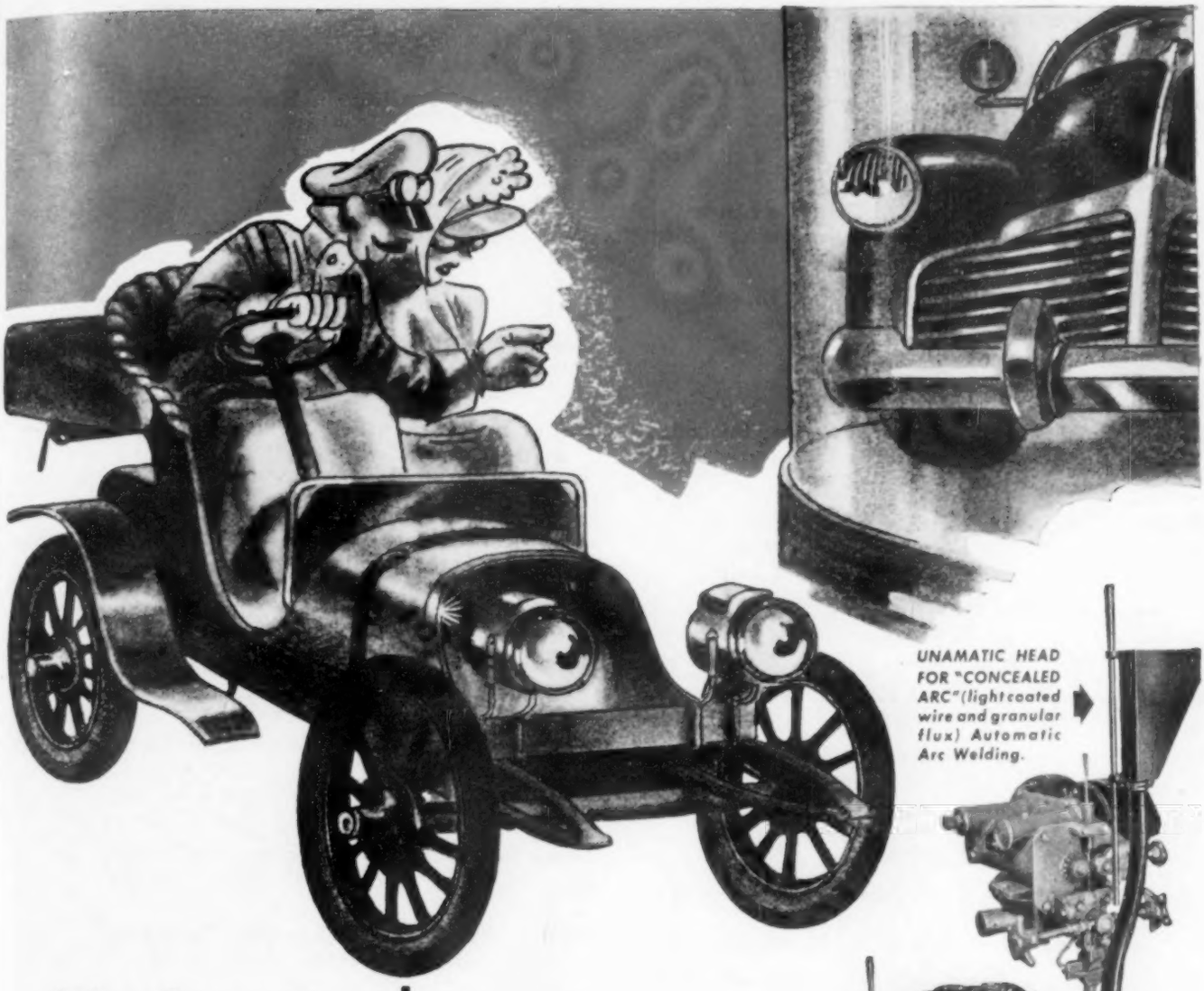
Power for Welding
by L. W. CLARK, The Detroit Edison Co.

Fundamentals of Heliarc Welding
by WILBER B. MILLER, Union Carbide & Carbon Res. Labs.

Recent Developments in the Application of Pressure Welding and Pressure Upsetting
by C. J. BURCH, The Linde Air Products Co.

NON-FERROUS

Spectroscopy Applied to Ferrous and Non-Ferrous Materials



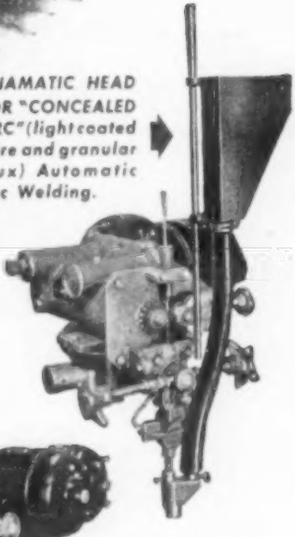
it's time to change....

Brings a chuckle, doesn't it? Yet this souvenir of the "horseless carriage" days isn't any more out of date than many of today's fabricating methods, when compared with the modern Unamatic processes.

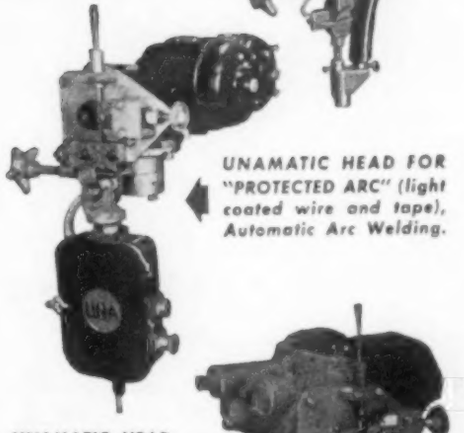
You might get quite a surprise yourself if you compared the speed, cost and quality of Unamatic arc welding with the fabricating method now being used in *your* plant.

Perhaps you would like to have one of our field engineers survey your plant to determine the advantages you may gain by employing the Unamatic processes. Write and we shall be glad to arrange it — without obligation to you, of course.

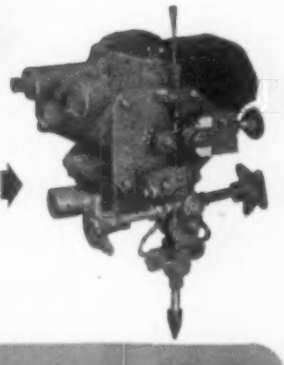
UNA WELDING, INC.
1615 COLLAMER AVENUE
CLEVELAND 10, OHIO



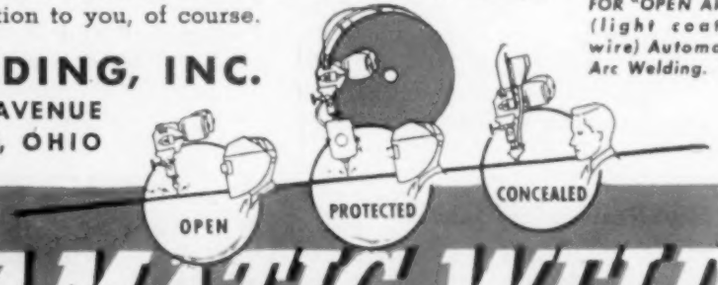
UNAMATIC HEAD FOR "CONCEALED ARC" (light coated wire and granular flux) Automatic Arc Welding.



UNAMATIC HEAD FOR "PROTECTED ARC" (light coated wire and tape), Automatic Arc Welding.



UNAMATIC HEAD FOR "OPEN ARC" (light coated wire) Automatic Arc Welding.



UNAMATIC WELDING

by WM. J. POEHLMAN, Research Engr., A. O. Smith Corp.

Gas Shielded Arc Welding of Aluminum
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Welded Gas Turbine Rotors
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Welding and Cutting by the Seabees
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by MILTON FORMAN, Welding Engr., Ingalls Shipbldg. Corp.

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STAINLESS STEEL

Factors Affecting Weldability of 18-8 Stainless Steels
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Shop Notes on Welding Stainless Steels
by VINCENT J. SHANAHAN, Welding Engr., Electric Steel Foundry Co.

Welded Stainless Steel in Gas Turbines
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